Royal Commission on the
Ocean Ranger Marine Disaster

Canada

Commission Royale sur le
Désastre Marin de l'*Ocean Ranger*

Newfoundland & Labrador

Report Two: Safety Offshore Eastern Canada

Conference Proceedings, 1984

The Royal Commission on the *Ocean Ranger* Marine Disaster was jointly established and funded by the Governments of Canada and Newfoundland

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The two reports of the Royal Commission on the *Ocean Ranger* Marine Disaster consist of the following four volumes:

Volume 1 **Report One: The Loss of the Semisubmersible Drill Rig *Ocean Ranger* and its Crew**

Volume 2 **Report Two: Safety Offshore Eastern Canada**

Volume 3 **Report Two: Safety Offshore Eastern Canada** ***Summary of Studies & Seminars***

Volume 4 **Report Two: Safety Offshore Eastern Canada** ***Conference Proceedings, 1984***

Volume Four is the Proceedings of the International Conference on Safety Offshore Eastern Canada, St John's, Newfoundland, August 21-23, 1984.

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PREFACE

In addressing the second part of its mandate, the Royal Commission followed a consultative process through which it sought opinions as well as factual information. A study program was undertaken, the purpose of which was to provide the Royal Commission with a concise but comprehensive review of the state-of-the-art in the main areas of concern. These studies, the various submissions received and the technical data gathered in the Part One Inquiry comprise the information base on which the Royal Commission prepared its second and final report.

The Conference on Safety Offshore Eastern Canada, held in St. John's Newfoundland, August 21-23, 1984 was organized by the Royal Commission in association with Memorial University of Newfoundland. It provided the first opportunity for public consultation on that information base and on the important issues that were being addressed. Summaries of most of the studies done for the Commission were distributed to participants before the Conference in the form of briefing papers. The main purpose of this Conference was to stimulate debate by experts on the basic issues and questions which the Royal Commission must address, and to illuminate possible new directions and opportunities for improvement. These proceedings incorporate the formal presentations made during the course of the Conference and summarize the discussion of those papers and commentaries. The editors have not attempted to conform the diverse styles of the papers presented at the conference, feeling that an accurate rendering of varied backgrounds and interests superseded the need for a uniform style of presentation. These papers provide a significant input to the Royal Commission in the preparation of the final report which will be submitted to the governments.

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INTRODUCTORY


Eastern Canada


INTRODUCTORY

WELCOME TO MEMORIAL UNIVERSITY OF NEWFOUNDLAND

r. L. Harris
resident
lemorial University of Newfoundland

It is an honour for Memorial University and a privilege to have among us so many distinguished Royal Commissioners, engineers, scientists, corporate executives and others who are concerned in a very real way with the matter at hand. I am particularly gratified to notice among the most distinguished participants some of those who have already honoured us by having accepted honourary degrees from this University. I am gratified as well to note that members of our faculties and, particularly, of Engineering and Medicine, are here and will participate in your deliberations.

Surely, in the context of incipient developments, there are few sets of deliberations that could have more consequence or more meaning than those with which we are now involved. The emergence of a major industrial activity in the harsh, Northern Atlantic environment certainly constitutes a major challenge to governments, to industry, to technical and scientific institutions and to all those who may be involved. It is a major challenge that principally revolves around the task of guaranteeing a measure of safety for those who exercise their business in such great waters.

I have a personal, though, precarious experience with those great waters that goes back for many, many years, since my family in its entirety wrested its livelihood from the waters of the Grand Banks. The names that were familiar in my mouth as household words in childhood were associated with the topography of the ocean floor lying on the Continental Shelf of North America, rather than with the land forms inward. I knew, as well, the perils of those regions, the dangers, the terrible fury of Atlantic storms, of seas, of gales, of fog, of drifting ice and of all the other associated hazards. In that environment I was continuously aware, as I now am, that the price of safety is eternal vigilance. More than that, it is eternal vigilance backed up by the very best systems and processes that the wizardry of our scientists and technicians can manage and that the wisdom of our political leaders can inform.

I am confident that this Conference will make a very significant contribution in this area and to the objectives that we all share. I am extremely happy to see that it is here on the campus of this University that the Conference is being held. I am happy that we have been able to have some small part in its organization and I am delighted, once again, to welcome you all most warmly and to wish very good luck as your discussions proceed.

OPENING REMARKS

Chief Justice
The Honourable T. Alexander Hickman
Commission Chairman

On behalf of the Royal Commission on the *Ocean Ranger* Marine Disaster, I welcome you all to St. John's and to the province of Newfoundland, Canada. We invited you to join us here, in the oldest city of North America, to take part in an unusual event. It is the first time a Canadian Royal Commission has ever sponsored an international conference. We regard the next three days as a crucial component of the public consultation process that we have embarked on in response to Part Two of our mandate. You have each been asked to participate because of your knowledge and experience in one or more of the key areas that affect safety offshore Eastern Canada.

There are many points of view represented at this gathering: those of people in governments both in Canada and in other countries; those of people in the industry: operators, drilling contractors, and service companies; and those of people from classification societies, consulting organizations, and educational institutions. There is assembled in this auditorium today a group eminently qualified to discuss the important issues that must be addressed by the Royal Commission. The issues at the heart of the challenging problem of improving safety embrace not only the relatively simple but most important questions of whether certain equipment is adequate and whether people are properly trained for the jobs they are doing, but require us to look for new insights into the complex relationships that govern these activities and for a fresh perspective on how effective they are likely to be over the next decade. This is essential if we are to ensure that an acceptable standard of safety is maintained in drilling operations off eastern Canada.

This Conference convenes with an acute consciousness that of recent years there has been a tremendous increase in the search for and exploitation of oil and gas reserves offshore throughout the world, which has resulted in a much more costly and hazardous operational challenge than is experienced by those working onshore in more favourable environments. Mankind has explored and exploited much of the world land mass in search of oil and gas; now emphasis is shifting to the remaining four-fifths of the earth's surface which is covered by water.

Those who work in the extractive industries, particularly offshore, recognize that there will always be an element of risk in their jobs. What they and their families want to be assured of is that every reasonable step has been taken to minimize that risk and to improve human safety. It is in pursuit of this attainable and desirable end that the Royal Commission looks to this Conference, composed of people who have had practical experience in offshore drilling operations in Canada

and in other parts of the world, for expert opinion and guidance. There is no substitute for uninhibited dialogue between knowledgeable persons committed to the safety of those who work offshore in the hostile marine environment of the North Atlantic off eastern Canada.

Conferences are normally arranged for the benefit of the participants. This one is different. It has been arranged mainly for the benefit of this Royal Commission. That is why it has been structured as it has and why we have invited only a limited number of people to attend from among the many experts who could have helped us with our task. In order for this Conference to adhere fully to its intended purpose your discussions must be frank and open which I am certain will be the case. The Conference is not designed to be a formal Commission hearing but rather a forum for learned discussion with Commissioners and staff sitting among you as eager but silent listeners. In this way, we hope to make the best use of your combined talents and of the very short time that is available to us.

As you all know, we finished our Part One inquiry into the loss of the *Ocean Ranger* last March and our report was released a week ago by the Governments of Canada and Newfoundland. Its publication marks the end of the formal quasi-judicial phase of our work which was concerned with establishing the facts or, if that could not be done, with arriving at a credible basis for our conclusions. We have done our best to provide answers to the two questions put to us in our terms of reference: why was the *Ocean Ranger* lost, and why were none of her crew saved? It is our hope that the Conference will not take up its time with debating the merits or demerits of the findings and recommendations in our first report.

We invite you rather to concentrate on the third question with which we are faced by our mandate which is: how can we avoid another disaster of this kind? This requires us to turn our attention to the future and to seek opinions rather than facts. One of the best ways to test opinion is in discussion by knowledgeable people with their peers. This is why we decided to organize this Conference in association with Memorial University of Newfoundland.

My colleague, the Honourable Gordon Winter, Vice-Chairman of the Royal Commission, undertook the task of chairing the Conference Program Committee. I thank him for the able way in which he conducted the by no means simple process of determining the content and structure of this Conference. We are all grateful to the Committee as a whole for bringing it to this point.

The Royal Commission is fortunate to have Dr. Omond Solandt as its Senior Advisor. Most of you are, I am sure, familiar with his distinguished career in government, industry, and public service in Canada and abroad. He has undertaken the onerous role of general Conference Chairman and I shall leave it to him to explain to you how we shall be approaching the various sessions and what we expect to achieve over the next three days.

It is with great pleasure, tempered only with anticipatory excitement, that I declare open the Safety Offshore Eastern Canada Conference and invite Dr. Solandt to take over the meeting.

CONFERENCE INTRODUCTION

Dr. O.M. Solandt
Conference Chairman

My contribution to the Conference at this stage will be to elaborate on some of the points made by Chief Justice Hickman, then to introduce our keynote speaker and finally to turn the meeting over to Dean Ross Peters.

You have heard from the Chief Justice about the important role that this Conference will play in the Commission's accumulation of material for its Part Two Report. In planning the structure and content of the Conference, the Committee has had to be ruthlessly selective in order to fit it into three days.

This Conference is the apex of a fairly complex information gathering process. First a series of 24 review papers was commissioned. They are intended to cover the present state of knowledge in every aspect of safety in offshore oil exploration and development. Study of this material led to the identification of four areas in which it appeared that the main problems for the future would lie. They are the topics of the sessions in the Conference:

- Environment and Design
- Man/Machine Interface
- Emergencies
- Regulatory System

In each session there will be introductory papers followed by a few selected discussants followed by general discussion. We hope that you will not ramble into other fields unless you feel strongly that some very important topics have been missed. But do be sure to state your opinions concisely. As the Chief Justice has said, the purpose of the Conference is to let the Commissioners hear your views. Unfortunately, in a three-day Conference with such a long agenda it is very likely that some important things will remain unsaid. You are strongly urged to present them either personally or in writing to the Part Two Commission Hearings that will begin in October.

The novel idea of holding a Conference as a major element in the process of gathering evidence for the Part Two Report arose within the Royal Commission. The Royal Commission felt that all the major actors in the offshore scene should contribute to the planning of the Conference. A Conference Program Committee was appointed with the Honourable Gordon A. Winter as Chairman and Commissioners Mr. Jan Furst and Dr. M.O. Morgan as members. The Federal Government is represented by Dr. A.E. Collin, Associate Deputy Minister, Department of Energy, Mines and Resources; the Newfoundland Government by Mr. John Fitzgerald,

Executive Director, Newfoundland and Labrador Petroleum Directorate; industry by Mr. Ken Oakley, Regional Director, Canadian Petroleum Association, Offshore Operators Division; and universities by Dr. G.R. Peters, Dean of Engineering and Applied Science, Memorial University of Newfoundland, who will soon appear as Vice-Chairman of the Conference.

Three members of the Commission staff are also members of the Committee: David Grenville, Secretary to the Commission who is the back stop for everything; Bevin LeDrew, Director of Studies, who commissioned and collected all the papers and will, with his staff, be acting as rapporteur for all the sessions; Neil Penney, the Conference Co-ordinator, and, finally, myself.

As the program took shape the Conference Committee saw that we needed someone to open the proceedings with a broad general look at the areas to be explored. Such a person should have a long and varied experience in industry, preferably including practical offshore experience in the most difficult environmental conditions. Because we were seeking the best in a very international field we knew that many of the candidates would not be Canadian but we all agreed that it would be nice if we could find a Canadian who could meet all the other requirements. The Committee feels that they have been doubly fortunate to have found a person who fully meets our exacting specifications and is a Canadian. Gordon Harrison is eminently qualified to give us his "Perspective on Safety" which will set the Conference on the right course for what I know will prove to be a very exciting and rewarding journey.

A PERSPECTIVE ON SAFETY

Gordon R. Harrison
Former President
Canadian Marine Drilling Limited

Safety is a serious issue in today's society, and it is a privilege for me to play a part in this international conference devoted to the safety of offshore drilling on Canada's East Coast.

We are here because of the tragic loss of the *Ocean Ranger*. Several official enquiries have already been made which have identified the causes of this mishap to be technical flaws in the ballast control system, the ballasting crew's ineptitude, and design deficiencies in the chain lockers and lower hulls of the vessel. I think we should be very careful in identifying cause. Personally, I see those factors cited as cause to be no more than part of a chain of events which made the vessel capsize and sink. They no more constitute the real cause than the final loss of buoyancy which at the end allowed gravity to pull the vessel to the sea bottom.

We need to examine the front end cause, the one that started this series of events. We need an understanding of what conditions exist in the drilling industry on the East Coast of Canada which could lead to the loss of a world class drilling vessel and her entire crew. We should also worry whether we are still courting disaster by the continuation of these drilling activities. If we are, we had better do something.

This Royal Commission has advised it is entering a new phase of its mandate in which it will be considering broad issues before making recommendations on public policy affecting safety of eastern Canada offshore drilling operations. In the course of its enquiry, the Commission will hear extensive representations of fact and judgement relative to safety issues. Before drawing on this material, the Commission advises it wishes to ensure what it hears is tested for correctness and credibility. Accordingly, we are being asked at this Conference not only to identify and critically examine matters affecting safety, but to subject these matters to discussion and debate. Obviously, we are fortunate the Commission has invited a prestigious group of international participants to bring expert knowledge on the matters set out in the conference program. In spite of the high qualifications of everyone here, it is my view it will be a difficult task to usefully impact safety of the offshore. What we are dealing with is a need for a new direction in the management of major projects of this nature. To do so will require change to the present order of things in society. There is nothing more difficult than that.

I must say I am encouraged by the atmosphere created here by the Royal Commission to examine the issues affecting risk and safety of the offshore drilling operations. We are told in our invitations to unshackle our thinking, to stimulate new ideas and to challenge each other's facts and opinions. It will, in my view, also

be necessary to seriously challenge the conventional wisdom both of industry and of government. If we do these things and are outspoken and bold, hopefully we will not disappoint our host. It will be instructive for us to examine the safety issues of other sectors of society to see what we can learn which might apply to the offshore drilling sector. Certainly, we should stand back and adjust narrow focus away from the particular weaknesses of the *Ocean Ranger* and see whether by broader focus we identify a common characteristic of all man-made mishaps of this scale. The question I believe we must ask is whether there is a flaw in the way we do things in society which is the root cause of these costly and tragic events.

The outlook for safety in our society is not good. Ignoring, if you can, the ever present danger of annihilation by nuclear forces, we constantly face the prospect of calamities on the scale of the *Ocean Ranger*. Generally, these events occur with little bias towards the land or the sea. Many people are familiar with well-publicized mishaps such as the capsizing of the *Alexander Kielland* in 1980 with the loss of 123 people, the collapse of skywalks into a crowded dance party at the Kansas City Hyatt Hotel in 1981 killing 114 people, the Marine barracks massacre in Beirut, Lebanon in 1983 with a loss of 241 lives and the more recent sinking of the drill ship *Java Sea* with a loss of 81 lives. But it takes a browsing of the literature to be reminded of the astonishing frequency of less-noted breakdowns in safety which regularly occur in office towers, hotels, auditoriums, bridges, sports arenas, trains, mines, as well as offshore oil and gas structures.

We need a new and different approach. The steady repetition of mishaps makes clear we are vulnerable and nothing now points to a change which will diminish this exposure. The postmortems we conduct for each major mishap may help reduce the chances of that particular set of unfavourable circumstances from occurring again, but these investigations fail to identify the common denominator which haunts the background of all these tragedies.

My assignment today is to provide a "perspective on safety", which I interpret to mean to try to find and explain the nature of this common denominator. More specifically, I am asked to examine philosophically the relationship between safety and technical considerations. There is, of course, a direct and vital relationship between the final integrity of an operating system and technical parameters such as the state of knowledge about environmental factors, the selection of design criteria, the choice of design safety factors, the qualifications of the designers, practices used for material testing and job inspection, setting up operating procedures, job training and the like. It is my view that these factors, taken individually, are already within our control. Rarely can the source of today's major mishaps be attributed to shortages in knowledge or shortcomings in technology. As in the case of the sinking of the *Ocean Ranger*, it is not that we are operating beyond the state-of-the-art. We have the knowledge and the tools to avoid these major slips. The source of our problem is very basic: we are heavy on regulations and bureaucracy, light on creativity and management control – a serious source of imbalance in a society, like damage to the middle ear.

As one reads the investigative documents available on the circumstances surrounding the loss of the *Ocean Ranger* and the loss of her crew, one is repeatedly struck by the single notion of things not being right. I am referring to two rather curious matters. Firstly, the apparent absence of single management accountability for the safety of life in the operations of the *Ocean Ranger* and its extensive and numerous support systems. Secondly, the lack of focus or importance placed on this absence by the investigative documents themselves.

The *Ocean Ranger* was owned by ODECO, a U.S. Company, and was operating under a U.S. Flag, thereby coming under U.S. Coast Guard laws and regulations. She was designed by American engineers, built in Japan and classified by the American Bureau of Shipping. She was operating in international waters under

the safety conventions of the International Maritime Organization but was under hire to drill exploratory permits issued to Mobil Oil and was therefore subject to regulations administered by COGLA and other agencies of the Canadian Government. Her major support systems, including supply boats, safety standby boats, helicopters and shore-base logistics were under the direction of Mobil through contracts with a number of third parties. She depended upon Mobil and Government Search and Rescue units for contingency planning for command of evacuation support equipment under emergency conditions. On board the *Ocean Ranger*, management and authority was shared in some manner by the ODECO toolpush, the ODECO ships' master and the Mobil drilling foreman. The ODECO toolpush and the Mobil drilling foreman reported to different company organizations on shore.

Let me say first, that this history and set of operating conditions I have just recited for the *Ocean Ranger* is not unusual. Indeed, it is conventional for the offshore drilling industry. Nonetheless, it is hard to escape the notion that, once drilling began on Canada Lands considerable ambiguity must have existed as to what management and regulatory authority dominated even for normal activities. For emergency operations there was room for even greater confusion. And prior to the start of drilling, if enquiry was made as to whether this would be a safe operation, who was one to ask? Was there a professional engineer who could certify that the vessel met critical design criteria for flotation stability and structural strength and that the sub-systems were also competent in terms of design, construction, licensing and operation? Was there a master mariner who could state with certitude that the vessel had adequate escape and survival systems? Could he provide assurance the crews were ready for emergencies? Were they familiar with the use and operation of the escape systems and had they practiced the complete evacuation with demonstrated skill and efficiency? Was there a suitable contingency plan for emergencies with all necessary support services and communications under a single command? Was there a senior officer of an operating company who could certify he had personally examined the professional engineer's work and was familiar with the critical environmental criteria and the safety factors used in the design? Was he personally satisfied that the engineer had properly conducted the design check and determined that the vessel's sub-systems were in good operating order and fully licensed? Had he similarly examined the master mariner and been satisfied with his assessments?

In other words, was there a senior officer of an operating company who had comprehensively examined all pertinent questions relating to the safety of the *Ocean Ranger* vessel and developed sufficient conviction about such matters that he would certify the vessel and all support systems were safe and ready for work? These are the questions that in my mind are important. But these are not the questions being asked. I think we should care less about compliance with the regulations of government and the codes of classification bodies and more about absolute accountability for safety. We should care whether there is a single responsible party who has done everything within reason to ensure that each drilling and support system operating on Canadian exploratory lands is safe against injury or loss of life.

The uncertainty about who is in charge and who is responsible is the common denominator to all large scale tragedies. When the 241 U.S. Marines were massacred while sleeping in a Beirut war zone, they had insufficient defence to stop a passenger car loaded with explosives from reaching and demolishing their barracks. It was reasonable to ask who was responsible and accountable for this lack of vigilance. It seems clear there was uncertainty as to whether this was a diplomatic or military mission. Consequently, it appears that neither the Department of Defense in the U.S. nor the Department of State was clearly given com-

mand and accountability for the safety of this outpost of young and vulnerable people. It resulted in tragic consequences.

Let's take another example. On July 17, 1981 there were 1500 people attending a party in the year-old Hyatt Regency Hotel in Kansas City. People were dancing in the large lobby and on two skywalks which spanned the lobby. Suddenly both skywalks collapsed and fell into the lobby killing 114 and seriously injuring another 216 people. It was the worst building failure in U.S. history. More than a dozen enquiries were conducted, including one by the National Bureau of Standards. The direct source of failure was apparently easy to determine. After construction was well underway, a design change was made through a telephone call between a consulting engineer and an engineer for the steel fabricator. After the accident, examination by the Bureau of Standards showed the redesigned skywalk was barely able to hold its own weight. Each engineer explained that he assumed after the phone discussion that it was the responsibility of the other to make the necessary calculations and neither did.

The cause of this calamity is also apparent. Seven major parties were involved in design and construction and all parties denied knowledge of who had overall responsibility. The architect who created the original design had little to do with job inspection as construction proceeded. Court documents show a construction job with a history of misunderstandings, oversights and safety problems. Mr. Edward Frang is Chief of the Structures Division for the National Bureau of Standards and has this to say in a quote from the New York Times: "Intuitively if you start seeing a history of management problems on a job, that's a building with a high probability of monumental failure." He goes on to say, ". . . there is a need for clear cut practices defining who is responsible for what in the construction process."

These examples and others demonstrate that safety, if put in proper perspective, will be seen as a management issue; lack of safety is a management problem. That, in my opinion, is all there is to it.

Listen to Eric Hoffer, a man who was first an uneducated longshoreman and then a social philosopher. "The only way to predict the future," he said, "is to have the power over the future." Now I think that is an awfully perceptive and important axiom which holds the crux of what we are dealing with here today. Let me illustrate. When President Kennedy announced in 1960 that the U.S. would have a man on the moon before the end of the decade, it was not that his gypsy fortune teller had that very morning read this event in his tea leaves. Rather the President intuitively sensed the project was an exciting goal which would raise the spirit of Americans and he was persuaded by the National Academy of Sciences that it was technically feasible and also would have enormous scientific and commercial spin-offs. He then charged the National Aeronautics and Space Administration (NASA) to perform the mission. NASA had single management authority for the program and, using 12,000 engineers, scientists, and technicians, was able to marshall scores of the best high-tech companies in the nation to serve under this authority. Nothing was left to chance and the best financed, best managed project in the history of the world, right on target, landed *Apollo II* on the moon surface on July 20, 1969. All of this was done with an incredibly good safety record. Yes, President Kennedy did predict the future, but only because he had power over the future. Moreover, when he delegated that power, he sensibly gave it to one single management authority.

"First we shape our structures," said Winston Churchill, "and afterwards they shape us." Quite so. On matters of safety our society is shaped by a complex structure of regulations and regulators embedded over the past century. By and large, this regulatory complex had been created in a manner which discourages or, at best is indifferent to, management responsiblity for safety. Indeed, incompre-

hensible as it may seem, we no longer seek to know who carried the responsibility, the authority and the accountability. Our system, by and large, leaves that matter to the lawyers and the courts.

The genesis of today's curious structure on safety may have occurred in Scotland about 100 years ago. In 1879, the Tay River Bridge, a vital railway link to the city of Dundee in Scotland, fell under the combined loads of a passenger train and furious gale-force winds. The bridge had been in operation for 18 months. It was the longest and considered the greatest bridge in the world and crossed the largest river in Great Britain. It was the dream, and briefly the crowning achievement of Sir Thomas Bouch, one of the great engineer-builders during a great bridge building era.

No one survived the accident. Seventy-five men, women and children died in this fall. It was human loss in scale about equal to that of the *Ocean Ranger* and other offshore drilling mishaps such as the *Alexander Kielland* and the *Java Sea*. Apparently, we have been packaging our man-made disasters in about this size for some time. A Court of Enquiry formed to examine the calamity delivered its findings to the British Houses of Parliament. Conclusions were the bridge was fatally flawed in its design, construction, and maintenance and that sooner or later was to be brought down by these inherent defects. Notably, the Board of Enquiry went beyond the question of cause and ruled on the matter of blame. They said Sir Thomas Bouch, the engineer-builder, was mainly to blame and specified further as follows:

- For the faults in design, he was entirely responsible.
- For the faults in construction, he was principally responsible.
- For the faults in maintenance, he was principally, if not entirely, responsible.

Sir Thomas Bouch, the Enquiry report went on to say, cannot escape his responsibilities. Indeed he did not. Several months before he had been knighted by the Queen for his triumphs as a bridge builder. Then, thoroughly discredited as an engineer, he went into seclusion to avoid the clamor for criminal proceedings against him. He died four months after he heard the censure from the Court of Enquiry.

I cite this bit of history because it seems this Tay Bridge disaster was pivotal in the setting of a course of events which brought us to where we are today. Several important points are worth noting.

It was a time in history when it was possible for a professional to have total technical control. Clearly Sir Thomas Bouch was a true bridge builder. He had the authority to control both the design and quality of the final operating product, starting at the drawing board and through to the quality control of the material and the workmanship. His responsibilities went beyond that. After construction was completed, he held authority for maintenance of the structure and control of the loadings placed on the structure during the operating stage.

Such a broad professional mandate in today's environment must be beyond the wildest dreams of Jerome Goldman, President of Friede and Goldman, and one of today's premier designers of world-class offshore mobile drilling units. Here are some excerpts from a speech given by Mr. Goldman in 1983, to the Symposium on the Safety of Life Offshore at Scripp's Institute of Oceanography: "When construction starts, the design has left the designer and becomes the responsibility of others." Mr. Goldman went on to discuss this lack of continuity in engineering responsibilities and he obviously harbors grave concerns about the consequences of this incongruity. "There is," Mr. Goldman says, ". . . no common ground for judging the quality of drilling units" nor for ". . . establishing and maintaining the quality of the drilling unit after it has left the yard." He goes on to say that as

things stand today "... classification societies must bear the responsibility and the integrity to review the design of the unit and to maintain the quality of construction both during the shipbuilding stage and throughout the operational life of the rig."

Now obviously although broad and continuous professional responsibility existed at the time of the Tay River Bridge disaster, something very serious was also missing. Firstly, although up until the Tay Bridge Enquiry engineers had extensive professional responsibility, they did not have a commensurate degree of accountability to society for mistakes. Secondly, corporate accountability was totally absent. The National British Railway received little criticism or blame for the Tay Bridge collapse and the officers of this Railway received none at all.

Society could have at this point simply decided to demand both professional and corporate accountability. Regrettably, society instead began to seek compliance with codes and regulations. This fateful step had the following consequences:

- The engineering profession, considered at the time to be one of the wonders of the world, began a decline in prestige from which it has never recovered.
- Governments began their attempt to create safety by demanding compliance with regulations rather than through demands for accountability.
- Finally, the definition of who is responsible and accountable for safety in the areas of design, operation, and maintenance began to blur, until today it is virtually impossible to tie down.

We must, in my view, redress this unsatisfactory state of affairs we have inherited from the past. First, we must re-establish broad and continuous professional responsibility. Secondly, ultimate responsibility must be given to a sector of society which has two distinguishing characteristics:

- It must have a track record which proves it can meet the challenge of the assignment.
- It must play a role in society where the stakes are high; that is, someone who will gain measurably by success and suffer grievously from failure.

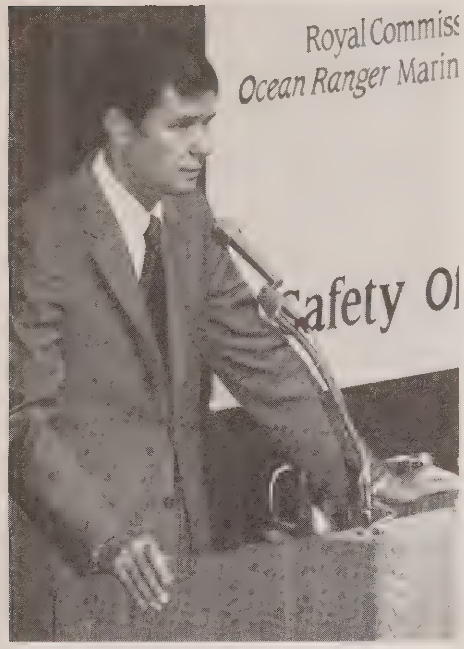
The obvious choice, and only choice in my view, is the private sector.

Ignor Ansoff in his book, *Strategic Management*, provides insight into the increasing difficulty for any function of society (such as safety) to hold its own in the fast moving world of today. He cites numerous studies made on the increasing speed of technological and social change. A common conclusion of these studies is that the time between emergence and the use of new technology is progressively shrinking. A companion aspect is that any particular social function benefits from this change only if it ties itself to one of today's fast moving commercial ventures. Safety, like everything in our society, is competing for talent.

Mr. Ansoff believes the key events in today's social and technological environment have become progressively 1) novel; 2) costlier to deal with; 3) faster; and 4) more difficult to anticipate. Given this environment, is there anyone who believes that the advances needed to assure safety in society should be placed in the hands of the classification societies and the regulating bodies of government?

One reply to this question is from the 1980 Burgoyne Committee Report which studied safety in the offshore United Kingdom. Regulations, the Report said, are "... slow to form and difficult to change; they are inappropriate in rapidly-changing technologies. What is needed for future projects is a more flexible system which can not only respond quickly to new problems, thereby generating improvements, but encourage a forward-looking attitude and put the responsibility for deciding what is safe where it belongs, with the Operator."

In my view, safety must stake its own claim to its fair share of the drive, the



Mr. Harrison graduated from the University of British Columbia in Mechanical Engineering in 1953 and has been in the oil industry ever since. In 1968, while with Mobil Oil Canada, he was responsible for drilling the first well on Sable Island, and in 1971 he established Mobil's first offshore drilling system for the Grand Banks. He also worked for a number of years with Dome Petroleum, and in 1976 as President of its subsidiary, Canadian Marine Drilling Ltd., he built and operated the first offshore drilling system in the Beaufort Sea. Mr. Harrison is presently located in Houston and is engaged in exploratory drilling and production on the U.S. Continental Shelf.

initiative, the creativity, and the success of the best in the private sector. It must clamor and fight for a position of top priority in the strategic plans of our successful corporations. Peter Drucker in his book, *Effective Management*, observes that the successful executive contrives to focus on the shortest possible list of priorities and the narrowest possible span of supervision. Safety must compete to become one of these areas of his focus. For society to achieve the best safety objectives, it is the energy of the senior executives of the best run companies that must be harnessed. Peter Drucker also says and I quote, "Whenever anything is being accomplished, it is being done, I have learned, by a monomaniac with a mission."

So let me say this in summary. Today I have offered the proposition that confusion as to management responsibility and apathy towards management accountability are the fundamental safety issues before this Royal Commission. I appreciate fully the usefulness of design codes and the value of regulations. I believe classification bodies are a progressive force in advancing vessel design and construction standards. I am concerned with the illusion that exists that compliance with regulations and the stamp of approval by classification bodies can in themselves provide offshore drilling systems with safe designs. I am for achieving safe performance through the dynamics of operator accountability rather than the passive compliance with safety standards. I am for continuity of professional responsibilities from the drawing board through construction monitoring and into the operating stage. I am for giving sole management authority to one entity for all aspects of offshore drilling projects in return for unambiguous accountability for safety.

What would it mean to offshore drilling on the East Coast of Canada if government authorities were to embrace the principles I describe? Firstly, responsibility and accountability would be vested in one single management with authority over the entire spectrum of design and operations for the offshore drilling systems applied to each exploratory permit issued by the government. The choice of this management authority would logically be the licensee/operator who would be accountable for the unsafe consequences of the entire operation.

As a first step, the Chief Executive Officer (or most senior operating officer) of the company would certify that he had engaged a professional engineer and was fully satisfied with the engineer's qualifications and experience. The professional engineer would be asked to provide a total design check and to certify that the drilling vessel met critical environmental design criteria for structural strength and flotation stability. Moreover, he would verifiy that all sub-systems of the vessel were competent in terms of design, construction, licensing, and operation. The C.E.O. would further certify that he had personally examined and was familiar with the critical environmental and safety factors used in the design check. He would state that based on his enquiry of the engineer, he was satisfied with the vessel's construction, that the vessel was in good operating order and was fully licensed. The C.E.O. would provide assurance that the crews were suitably trained and would be at all times ready for emergencies, that they were familiar with the escape systems and had practised complete evacuation with demonstrated skill and efficiency.

Now under today's conditions the C.E.O. would be faced with a fateful choice. Either he could state with certitude that the vessel had adequate escape and survival systems if the vessel needed to be evacuated, or he could call a spade a spade, and point out that the evacuation and survival systems specified by government code and regulations are useless in sea conditions relatively common to the East Coast of Canada. Obviously with today's state-of-the-art he would make the second choice. With this choice, he would set out a time schedule for the research, development, and demonstration of evacuation and lifeboat survival capabilities which meet the ocean conditions off the East Coast of Canada. The

government, faced with this candor and commitment would undoubtedly grant the permit to begin drilling operations with the knowledge that:

- Accountability for safety of the entire operation of the exploratory permit was inescapably clear and that severe penalties could apply for non-performance.
- The serious gaps in the technology of escape and survival systems for all ocean vessels would rapidly disappear.

Over the last 20 years, the petroleum industry has progressively forecast that oil and gas will be found and produced in deeper and deeper waters under more and more severe ocean environments. Then, systematically using technology which competes in ingenuity with that of the NASA space program, this industry has advanced its operations from ten feet of water depth to five thousand feet, and from protected shoreline embayments to the most threatening ocean environments of the world. In short, it is an industry that has proven Eric Hoffer's intriguing thesis that with power over future events, one can predict future events.

These achievements by the petroleum industry have been obtained by management skills that can be applied equally well to one problem as another. Once clearly given the job to create a safe future for drilling on the East Coast of Canada, the industry will respond with unrelenting purpose, and once delegated the professional responsibilities to achieve this goal, I have absolute confidence that the creative talent and drive of the professional engineers, scientists, and architects engaged by our industry will once again prove that simple and powerful axiom: necessity is the mother of invention.

2

ENVIRONMENT AND DESIGN


Safety Offshore Eastern Canada

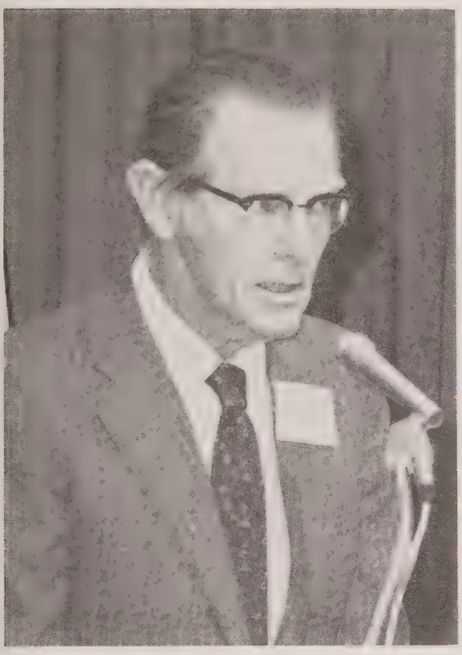
ENVIRONMENT AND DESIGN

INTRODUCTION

The studies into the environment examined the physical environment of that part of the East Coast offshore where the offshore drilling operations take place. Emphasis was placed on the adequacy of available data and current data acquisition procedures and programs. Also examined were severe and limiting conditions, and their detection or prediction.

The studies into design aspects addressed the process of design conception, construction, classification, and certification of offshore structures and their ancillary equipment. The operational limitations and upkeep requirements of these structures and their equipment were also considered.

This Technical Session was chaired by Mr. R.A. Hemstock, an engineer with a lengthy and prominent career who is currently the President of the Canadian Council of Professional Engineers. Mr. Hemstock who holds an M.Sc. from the University of Alberta, worked with Imperial Oil Ltd. from 1948 to 1977; in those latter years he conducted research on the evaluation of engineering problems associated with the developments in the Canadian Arctic. From 1978 to 1983 he was Manager of the Environmental Division and Director of Hardy Associates and had primary responsibility for providing consulting services on environmental matters to the energy industry. Currently President of R.A. Hemstock Engineering Services Ltd., Mr. Hemstock has been a member of various advisory committees of the National Research Council, has represented the Canadian Petroleum Association on the Advisory Committee on Arctic Land Use Research, has represented Canada as a member of the Canadian technical exchange with the U.S.S.R., and was instrumental in the formation of the Arctic Petroleum Operators Association and is past Chairman of that organization.



Dr. W.L. Ford
Oceanographer

Dr. Ford holds degrees from the University of British Columbia, Northwestern University, the National Defence College, and honourary degrees from the University of New Brunswick and Dalhousie University. During his lengthy career, he had held positions with Dupont, Woods Hole Oceanographic Institute, and the Defence Research Board. In 1965 he was appointed Director of the Atlantic Oceanographic Laboratory at the Bedford Institute, a position he held until his retirement in 1978. Throughout his career, Dr. Ford has represented Canada on various international oceanographic committees, and he is a member of the Ocean Industry Advisory Committee and C-CORE's Research Advisory Committee. Since his retirement he has been an oceanographic consultant.

PAPER B1

Critical Environmental Factors off Eastern Canada

The goal of the Royal Commission in the Part Two Inquiry is to identify practical means of improving safety of our offshore drilling operations. To this end a number of studies were commissioned, six of which dealt with the physical environment under the headings: weather forecasting, ice, climatology, oceanography, wave climate, and seabed (1, 2, 3, 4, 5, 6). These six reports were subject to peer review and subsequently to vigorous comment at a recent workshop (9) attended by the authors, peer reviewers, and other specialists from the industry, the oceanographic and meteorological communities, and regulatory agencies. This paper presents the highlights from this process as I see them.

Offshore exploratory drilling got underway in our area in 1966; since then many rigs of various designs operating under a wide variety of conditions, some throughout the winter months, have drilled about 200 holes. There has been one tragedy, the loss of the *Ocean Ranger*. That incident has not been directly attributed (7, 8) to environmental factors, though they played a devastating role after things went wrong.

Notwithstanding the dark shadow thrown by this disaster, the overall impression is one of an industry actively concerned with those aspects of the physical environment bearing upon the safety of operations, including extensive contributions to the data.

Before getting into an examination of specific environmental issues, I want to make a general comment on the differences of opinion that are held concerning the adequacy, from a safety point of view, of our environmental knowledge. I suggest these differences fall into one or the other of two schools of thought. There are those who are of the opinion that the present levels of knowledge and of information services are quite adequate to run a safe exploratory operation. It follows therefore that purely on the grounds of safety, few if any, new initiatives vis à vis environmental factors need be undertaken. This is not to say that they are not wanted for reasons of improved efficiency. This school tends to treat good safety practices and sound economics as unrelated activities. The other school holds the view that good safety practice is good business, especially in the long run. For example, it would indeed be surprising if a substantial improvement in the reliability of weather forecasts, especially of severe events, leading to reductions in lost time in operations and hence increased efficiency, did not also contribute to the maintenance or improvement of safety. A reduction in the chances of being caught off-base by a sudden unsuspected change for the worse in the weather surely is a positive term in the safety equation.

Weather and sea state forecasts, first of the six studies, are very much an integral part of daily operations of the rigs, and of the supporting helicopters and supply vessels. There is a strong consensus for improvement in the precision of forecasts with the increased level of confidence in their validity that would ensue.[1]

Substantial improvement in these forecasts will not come easily. Although all rigs operating in our offshore are part of the observational network, the present real time coverage of weather and sea state in the area is far from adequate when compared to land based observational standards. Significant improvement in the quality of the marine forecast requires a marked increase in the real-time data base through, for example, the provision of many more observing points at sea, or greater use of satellite technologies. Beyond this, however, is the problem of mesoscale phenomena, like squalls and polar lows, capable of producing hurricane force winds. They are small enough to go undetected in the synoptic scale observing net as they are born, evolve and decay. Moreover the physics of these events is poorly understood, thus holding up the development of models capable of useful mesoscale forecasts even given the necessary data base.

This problem is not of course peculiar to the Eastern Canadian Offshore. It is receiving high profile attention worldwide. In Canada, following a mesoscale meteorology research planning workshop in January 1983, a meeting was held to examine the research requirement on the East Coast, specifically "user" and "provider" viewpoints. Detailed plans have been developed to investigate mesoscale processes within major Atlantic winter storms and have gone forward to the Office of Energy Research & Development for funding, strongly supported by proponents in industry, university, and government (15).

An experimental project to assess the feasibility of moored buoys as a means of improving the observing network was undertaken last winter jointly by Mobil Oil, Petro-Canada, Atmospheric Environment Service (AES), and Atlantic Oceanographic Laboratory/Bedford Institute of Oceanography (BIO). The buoys were moored at three sites, one buoy at each, along the southern flank of the Grand Banks. They transmitted atmospheric pressure and sea surface tem-

perature via satellite to AES throughout the winter. An analytical study is now in progress at Dalhousie Univerity to determine whether the additional pressure measurements add significantly to the observing and forecasting of weather systems on the Grand Banks. If yes, an encouraging step will have been taken towards improving relatively soon and at reasonable cost the offshore real-time data base and hence the forecast.

Aside from advances in the basic product, better "packaging" and "delivery" can and should be provided by improved forecaster/client relations, verification procedures and training of personnel doing interpretation on site. Benefits should ensue in the short term from early implementation of these measures pending solution of the underlying problems of weather forecasting.

The second study deals with ice. The combination of icebergs and pack ice in eastern Canadian waters presents unique difficulties for exploratory drilling, let alone production. The industry has successfully addressed this challenge through the development of a system of ice management. The essence of the system is the avoidance of collision with ice. In ice infested waters such as the Labrador Shelf, the avoidance policy limits operations to the pack-ice free season and typically to dynamically positioned drilling vessels capable of a quick departure if threatened by an iceberg. Further south, in the Hibernia area, semisubmersible drilling units are in use year around. Their orderly withdrawal to avoid a developing ice threat requires a considerably longer time than with a dynamically positioned vessel. Without going into details, the system depends critically upon detection and tracking of any ice in the vicinity, plus the establishment of alert and safety zones appropriate to the type of rig on site. For example, disconnect procedures, both for drilling and anchors, are initiated when an iceberg comes within 40km of an anchored rig (2).

In the four to five years of all-season operations at Hibernia, only in the past two has ice made an appearance (2). Surveillance experience under winter ice conditions is therefore quite limited. Within the past year an important improvement was achieved by the establishment of coordinated industry-government surveillance serving a common operations centre and using every means of siting ice: visual and radar from aircraft, helicopters, and ships. Industry continues actively to promote improved detection and tracking of sea ice and bergs. The focus is upon developing better conventional marine radar and upon airborne imaging radar (9). Also an Environmental Studies Revolving Funds project is in progress, 1984, to conduct field investigations on the capability of synthetic aperture radar and side looking radar to detect icebergs, bergy bits and growlers under various conditions (10).

Detection and tracking is a particularly challenging problem under conditions of low visibility and heavy weather. At the Workshop (9) NORDCO presented some results of recent calculations on the ice detection capabilities of conventional marine radars as a function of sea state for an ice target of 20m length, 5m high, a large bergy bit. In sea state 0 to 1 the probability of detection is calculated to be 90% out to about 7km. As sea state increases, sea clutter also increases, downgrading detection in the near range. Thus at sea state 4, detection is less than 10% from 0 to 5km, rising to 25% at 7km, and then falling off rapidly. By sea state 6, clutter extends out far enough to reduce detection to virtually zero at any range.

Lever (11), reporting on a model study of behaviour of ice in a heavy sea, concludes that ice masses, which are small compared to the wave length, move as particles of water. Thus, for example, maximum full scale velocities of 4.5m/s would be possible for a 4,300 tonne bergy bit in a 14m, 12 sec. storm wave. Its kinetic energy would be equivalent to a 300,000 ton berg moving at 1 knot. Some people have expressed the opinion (9) that while such impact studies may be very important when considering production systems, they are not particularly relevant to safety in exploratory drilling because they do not contribute to the strategy of avoidance. Not everyone accepts this position. The probability of a piece of ice slipping through the surveillance net under conditions that could lead to a significant encounter, although generally believed to be remote, does not appear to have been quantitatively examined. However, Lever (9) in association with C-CORE, is planning to undertake the estimation of the joint probability of encounters. Such studies should be an important contribution to the assessment of the level of safety being achieved by the ice management system in the Hibernia area.

Icing, a term which includes accumulations on structures due to rime formation, as well as spray or precipitation freezing on contact, attracted attention in three of the studies (1, 2 & 3) and at the Workshop (9). On the basis of its operating experience to date, the industry considers (9) it is managing operations so that icing situations do not endanger the safety of rigs, supply vessels or helicopters.

From the point of view of the weather forecaster and climatologist, icing is regarded as a problem of considerable concern for safety offshore. The widely desired improvements in the precision of forecasts, discussed earlier, certainly apply to the specifics of icing forecasts, and therefore to icing sensitive operations like sea/air rescue and helicopter services. The state of knowledge about icing in the offshore is regarded by meteorologists as being very inadequate (2, 3) and in need of systematic long term investigation. For example, the present data base does not permit the description or the estimation of the probability of occurrence of extreme icing events. However, the studies have not revealed any reports of serious icing on any of the numerous rigs which have operated where and when icing is a distinct possibility. Although this suggests serious icing events may be uncommon, it is important to recognize there is no scientific basis available today on which a reliable estimate can be made of the probability of their occurrence.

Climatologists consider most aspects of the marine climate to be inadequately documented (3). The primary cause of this weakness is a general lack of base line data for *all* parameters, particularly in winter and in northern waters. Even for wind, the most important parameter, the data base is insufficient to define temporal and spatial variability, the effects of structures on the wind field or extreme values. Various approaches to estimating the 100-year return wind at Hibernia gave figures ranging from as low as 60 knots to as high as 140 knots (9). Such uncertainty leaves a designer or planner in the unsatisfactory position of probably having to overdesign while not necessarily contributing anything to safety.

The industry, working with the available climatology, has been able to develop operations over the past 18 years under a variety of severe conditions without a single serious accident directly attributable to a mis-judgement of a climate factor. The inference is that there is no requirement, from the operational viewpoint, for improved climatology strictly for purposes of enhancing the safety of operations. In the short term this may be evident, but is it so in the long run? Improvements in this field are inherently a long term process dependent upon development of not only the spatial aspect of its data base but, more importantly, the temporal aspect which cannot be hurried. Experience suggests improvements will be made and will be used in the industry for many purposes including higher standards of safety.

A word of clarification about oceanography is in order. Although wave climate is clearly an oceanographic matter, it was given a study of its own because of its outstanding importance as a limiting environmental factor. The oceanographic study, dealing with physical oceanography generally, excluding waves, concluded that the field is adequately developed for purposes

of ensuring safety in exploratory and delineation drilling (4). Two matters did stand out, however. The first concerns iceberg trajectory prediction of an individual berg in a time frame of up to a few days. There have been a number of attempts to achieve useful predictions without much success. A new approach is underway by the Atlantic Oceanographic Laboratory at BIO using a recently developed acoustic current meter which permits the rapid determination of the current field surrounding a berg (15). The aim is to assess whether there is any real possibility in the foreseeable future of making trajectory predictions with sufficient accuracy to be useful in an ice management system.

The second, featured prominently in both the oceanographic and wave climate studies, is a requirement for the accumulation of a few series of simultaneous current, wind and wave measurements selected at rig sites offering a variety of environmental conditions. One purpose is to establish a relationship between current and the local wind and waves, thus permitting hindcasting of extreme currents which is now not possible. The other is to try to achieve a better understanding of wave/current interactions which have important implications in sea state forecasting, as well as wave climate.

Oceanographic matters of concern to the industry are being addressed on a continuing and cooperative basis by a joint committee made up of representatives from industry, universities, and government (17). Its principal focus is the physical oceanography of the Grand Banks as it relates to offshore development.

Waves are the most energetic environmental factors faced in offshore operations. One very important aspect of wave information has already been discussed as part of weather forecasting, i.e. the wave forecast, but now I want to touch upon outstanding issues in wave climatology. The wave climate study (5) reported on requirements of owner, design, classification, and regulatory organizations. These organizations are on record as wanting good data on wave climate generally, including spectral analyses and reliable estimates of extreme wave heights, periods, and crest heights. Such requirements are not, of course, exclusively related to safety.

Today there are still major gaps in our data base. The Labrador Shelf and northern waters are, for these purposes, in poor shape. The situation is much better in deep water of the southern areas; the data on Hibernia is generally agreed to be approaching a level where a reliable 100-year return wave height estimate can be made. However, moving into water shallow enough for bottom effects to play a major role, as around Sable Island, the state of the art leaves something to be desired. Much remains to be learned about the physics of the complex wave trains as they move into shallow water, often under the added effect of strong currents, before a reliable description can be provided of this special case of wave climate and its extremes.

The quality and precision required of environmental data, such as wave climate, for planning of production systems is of a higher order than that necessary for exploratory drilling. The wave climate in the shallow waters of the Venture site is a case in point and Mobil have investigations underway to support planning for the development of that field (13). As a spin-off, any resulting improvements in the knowledge of extreme events in the area will provide opportunities for additions to the safety margin in ongoing exploratory operations.

The Mobil studies are geared to producing results in a time frame of months and cannot be expected to dwell upon advancing the physics of wave behaviour. Scientists in Germany, Holland, and the United Kingdom have reported, recently, some success in modelling wave generation and propagation in shallow North Sea waters (12) and it is mentioned here as an indication of the growing attention being given to the subject. There is an evident need for ongoing, longer term research to resolve this scientifically difficult problem as it applies in our own waters. By its nature, it should be a joint undertaking of industry, university, and government to take full advantage of the independent and open appraisal of both project planning and project findings this approach offers. There are established precedents for this way of doing research business.

From the operating side, two requirements on wave climate were identified at the Workshop (9): one, the provision of more reliable estimates of the 100-year return wave in connection with proper deck clearance; the other, wave spectra for a possible role in that part of the spectra where the frequency of occurrence of wave impact on the structure may be strongly related to fatigue.

The Seabed study (6) concludes that geophysical surveys, and regional mapping do not provide, of themselves, sufficient information for siting drilling operations and that site specific geotechnical investigations are necessary. This is recognized in the industry and site specific surveys are standard practice.

The principal issue to emerge from the Seabed report (6) and ensuing discussions (9) was bore hole sampling as an essential element in determining the suitability of a site for positioning a jackup rig. Punch through is an important cause of failure in jackups (6). The probability of foundation failure in offshore units, though remote, is about ten times greater than on land (6). Geophysical and surficial geotechnical survey techniques cannot be relied upon, solely, to ascertain the presence or absence of potential punch through conditions (6). The addition of bore hole sample analyses provides for a more confident assessment. At the present time the use of bore holes is discretionary in surveys for siting jackups; a mandatory requirement is indicated as a contribution to safety.

To sum up: no inadequacies were identified in the state of knowledge about our marine environment so glaring as to constitute an imminent threat to safety in the offshore, given good operational safety practice. Nevertheless, it is evident there are many improvements to be made, generally incremental, which taken together, will give prudent management the opportunity to enhance safety on a broad front. Economical and timely realization of improvements would likely best be achieved by sustained joint research and development programs. Although there have been an encouraging number of cooperative arrangements put in place recently, greater reliance on this approach would surely be a sound investment in meeting the evolving research and development needs in respect of the physical environment that the industry will generate as it moves ahead in the decades to come in offshore eastern Canada.

[1]The weather forecast study by Seaconsult, Limited, (1) has been extended to permit evaluation of the operators' use of the forecasts and of what they see to be these needs. A report on this new work is not complete; it is therefore not reflected in this paper

References

(1) Weather Forecasting Services for the Canadian Offshore. Seaconsult Limited, February 1984.
(2) A Review of Ice Information for Offshore Eastern Canada. NORDCO Limited, June 1984.
(3) A Review of the State-of-the-Art in Marine Climatology on the East Coast of Canada. V.R. Swail and L.D. Mortsch. Canadian Climate Centre, Atmospheric Environment Service, April 27, 1984.
(4) Oceanographic Information for the Eastern Canadian Offshore, Adequacy for Exploratory Drilling. Seaconsult Limited, April 1984.
(5) An Assessment of the State of Knowledge of East Coast Offshore Wave Climatology. J.R. Wilson, Marine Environmental Data Service and W.F. Baird, W.F. Baird and Associates, June 1984.
(6) The Adequacy of Available Seabed Information as Input to Design Criteria and Operating Constraints for Eastern Canada Offshore Exploratory Drilling. Jacques, Whitford and Associates Limited, January 31, 1984.
(7) Capsizing and Sinking of the U.S. Mobile Offshore Drilling Unit *Ocean Ranger* off the East Coast of Canada. February 15, 1982, Marine Accident Report by the National Transportation Safety Board, February 15, 1983. Washington, D.C. Report No. NTSB-Mar-83-2.
(8) Commandants' Action on the Marine Board of Investigation convened to investigate the circumstances surrounding the capsizing and sinking of the Mobile Offshore Drilling Unit (MODU) *Ocean Ranger*, O.N. 615641, in the Atlantic Ocean on 15 February 1982 with multiple loss of life. United States Coast Guard, October 21, 1983.
(9) Proceedings of the Eastern Canada Offshore Exploration and Physical Environment Workshop, June 27-28, 1984, St. John's, Newfoundland.
(10) Environmental Studies Revolving Funds, Update, Vol. II (1), p. 7, February 23, 1984. Canada Oil and Gas Lands Administration, Ottawa.
(11) James Lever, "Wave Action on Icebergs and Bergy Bits" *Atlantic Energy News*, May 1984, p. 15. Also C-CORE Report No. 84-7.
(12) Personal Communication from W. Perrie, Atlantic Oceanographic Laboratory/BIO.
(13) Venture Environmental Impact Statement Addendum. Mobil Oil Canada Limited, March 1983, Section 3.1.6, Study Programs. Personal communication July 1984, Mobil confirms their present program on wave climate for Venture is that described in the above Addendum.
(14) CMOS 1983 "Mesoscale Meteorology Research Planning Workshop", Canadian Meteorological and Oceanographic Society, Scientific Committee, Annual Report.
(15) Personal Communication from J.A. Elliott, Atlantic Oceanographic Laboratory/BIO.
(16) Personal Communication from C.S. Mason, Atlantic Oceanographic Laboratory/BIO.
(17) The Grand Banks Physical Oceanography Steering Group. Chairman, J.Buckley, Petro-Canada; Members: J. Benoit, Mobil Canada, C. Garrett, Dalhousie University, A. Hay, Memorial University, C. Mason and B. Petrie, Atlantic Oceanographic Laboratory/BIO.

Note: References 1 through 6 are reports submitted to the Royal Commission on the *Ocean Ranger* Marine Disaster.

COMMENTARY ON PAPER B1

L. Draper
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Dr. Ford has comprehensively summarized the environmental factors in these waters and I thought that perhaps the most useful comments I could make would be to sound a word of caution on the accuracy of wave predictions. I am as guilty as anybody else in letting engineers get away with the thought that wave predictions are really precise; inadvertently we tend to give this kind of impression.

I have a number of questions about waves, to which I really do not know the answers, the simplest one perhaps is: "What do you mean by the crest of a wave?" It seems obvious, but it really is not. The distance between 100% water and 99% air is probably a couple of metres in a really severe storm. So, where is the crest? What do you mean by the crest? The apparent height on your recorder probably lies somewhere within this two metre range, but just where it does effectively lie is open to speculation. As a consequence, there is a large amount of water travelling horizontally above the level at which you think is the crest of the wave, and it is moving at 30 or 40 knots. So I do not really know where the crest is likely to be in any given sea.

Another thing I do not know is: "What is the actual distribution of crests?" If I use words which are not familiar to you, like Rayleigh distribution, don't worry, it is the conclusions which are important. It is tacitly assumed that wave height distribution is thought to be Rayleigh, and this is so in most conditions we can measure. It has not been proven to be so in extreme wave conditions where things go drastically non-linear. In fact, it is only strictly true for a narrow band spectrum in ordinary waves.

Another question is: "How accurate are our measurements?" Instruments are by no means perfect. Even if you have a calibration done to within a few percent over the whole frequency range of the instrument, you can not guarantee that all recorders respond instantly and exactly to the wave profile. We think of a wave record as being the history of the water surface through one vertical line with respect to time. The waverider which is much the most successful wave recorder in the world, goes round in something near to a circle, with a diameter equal to the wave height. It does not tell you what is happening at this particular point; it tells you what is happening here now, and 50 feet over there 5 seconds later. At the very least, it distorts phase relationships in the wave records.

What are the laws governing the distribution of wave height extremes? I also have to be careful with statisticians and not always believe everything they say. They recommend that you fit a thing called FT-1 distribution to the data. You have, say, 3,000 measurements of waves in a year on a typical station. So they say: "We have 3,000 samples; we can make beautiful predictions," and if you let the statisticians get away with it, they come along and at Seven Stones light vessel, which is still operating southwest of the U.K., they will give the following estimates of the height of the hundred-year wave:

FT-1 fit to Seven Stones data

Year	H_s, 100	95% Confidence Limits	
1962-63	15.79	15.73	15.86
1968	13.87	13.82	13.93
1969	13.39	13.34	13.44
1971-72	16.52	16.45	16.58
1972-73	14.61	14.55	14.67
1973-74	16.33	16.26	16.39
1975-76	13.71	13.66	13.77
1976-77	16.09	16.03	16.16
1982	16.84	16.88	17.01

In the first year of measurements, we had the prediction of 15.79. (In practice, we can completely ignore the second decimal figure of significant wave height.) It appears that we have a 95% confidence of it lying between 15.73 and 15.86. Marvellous! We have really arrived. The prudent, however, might say that perhaps the climate does change a bit, so let us try another year. It so happened that the next year's data for this particular location came up with 13.87 metres and you say, "Oh dear!" We then did this for 9 separate years of data, and in fact the 95% confidence limits do not even overlap! So, where do we go from there? In fact, the FT-1 is not really designed for that sort of thing, if you are honest about it, but what it is designed for is looking at individual maxima from each year. Then it has a sounder basis, with some theoretical justification, but this is a much weaker although more plausible assumption, and gives wider confidence limits.

Using the technique for which the FT-1 was designed on all the data from 9 years at Seven Stones, the 95% confidence limit lies between 90% and 132% of the value you have actually predicted. If you had been lucky enough to have 20 years worth of data, and you had predicted the same answer, the 95% confidence limit would then come down to between 92% and 115%. So, do not go home thinking that we can get it within half a metre, we can not.

Another nasty problem is: "How well do we sample the wave data?" We have a station, using a waverider, which is in waters comparable to Hibernia, but off the west coast of the Outer Hebrides where conditions are, in fact, more severe. One visiting scientist from New Zealand, B.R. Stanton, recently showed that waveriders preferentially lose the more severe wave records; the gaps are bigger in bad weather. That is not news to anybody, but what it does do, if you use standard techniques and ignore that fact, is underestimate the extreme condition. Mr. Stanton has shown that it would appear to be that the extreme conditions would have to be estimated to be at 16% more than the initially predicted value for this very severe location. Even now, we are still learning.

Wave conditions in Hibernia are about the same as in the northern North Sea, by and large; wave periods are probably somewhat longer because it is on the edge of an ocean which the North Sea really is not. Some of these problems are unquantifiable, although perhaps I could make a guess on the basis of our 20 years' experience in the North Sea; I do not know how many rig and platform years that is now, but it must be quite a large number. There has been no catastrophic incident ascribed to misunderstanding the waves in these 20 years. I could stick my neck out and say that the derived values, the ones which we have published, are probably within ±10% of the true value, if there is such a thing, for typical stations. Even so there is no evidence at all for overestimation of wave height. We have not so severely overcooked it that there are no accidents. We can not sit back and be complacent.

There are various other comments I could make about hindcasting, but the ultimate goal is to be able to hindcast rather than measure. It is not likely that this technique is going to become really reliable within the next ten years.

Just one thing I think I ought to say about the mention in Dr. Ford's paper about the Hermes data buoy, measuring, I think, atmospheric pressure and temperature over sea water. It does seem a pity to me that, if you are putting out a buoy, you do not go for the best which is available. In the U.K. we had DB-1 (Data Buoy 1) out in the Western Approaches for about three years and it performed exceptionally well; it really produced a lot of data. We have now gone to the next phase, to slightly smaller buoys called DB-2 and DB-3, and they are deployed southwest and northwest of the U.K. They cost a quarter of million pounds each, but they have a guaranteed data return, or severe financial penalty in lieu of 95% of the data. Everything is duplicated; the data are transmitted via METEOSAT every hour and a small amount every three minutes via ARGOS (the latter mainly for position fixing, but not entirely). Data are quality controlled to an IOS-agreed standard and data can be available within minutes of measurement, if you really need an instant response. It seems to me that a million dollars for the two buoys out in the water, upwind (or upwave), can not really be construed as being a luxury when you are concerned with the safety of a structure of the size of the *Ocean Ranger*. I think one ought to consider the possibility of spending a little bit more money in that direction.

My message is that we really ought to make a thoughtful assessment of everything concerned with the environment. As Mr. Harrison said, do not be complacent. Make somebody responsible for ensuring that all aspects are as reliable as can be achieved; in other words, absolutely everything must be checked in all aspects. Do not assume that because it is in print that it is actually gospel; it is not written on tablets of stone at all.

COMMENTARY ON PAPER B1

Dr. W. Speller
Supervisor, Offshore Assessment
Environmental Affairs, Petro-Canada

As a discussant of the environmental issues pertaining to the safety of offshore exploration operations, I have had the benefit of reviewing and responding to the six environmental reports prepared by the Commission, as well as the opportunity of attending the recent workshop on eastern Canada exploration and physical environment.

From my perspective, these activities have been both educational and surprising. Surprising, in that some government agencies and some consultants did not always appreciate or understand how environmental information is used to plan offshore drilling operations or support day-to-day activities. The workshop served a very educational role for all participants and the results have provided the Commission with a balanced perspective of the environmental issues affecting offshore hydrocarbon exploration.

With regard to the paper prepared by Dr. Ford, I concur with the contents, conclusions and tone of its various parts. It is a fair and balanced review of the papers, the physical environment workshop and ongoing physical environment research and development efforts in Canada. In my opinion, our discussions of the environmental issues today will centre not on what we should or should not be doing, but rather they will focus on the emphasis we should place in one direction or another to achieve our goals effectively and efficiently. With this in mind, I believe it is worthwhile summarizing several important basic points, which I believe will help to focus our discussions on the offshore physical environment.

The first point is that we do not have, nor can we be ever expected to achieve, consistency in the quality and quantity of environmental information available for different sectors of the Canadian East Coast, let alone other offshore regions of Canada. Where the search for offshore resources or the transportation of commerce at sea is carried out in new areas, there will always be minimal environmental information to work with. Only through technological developments, such weather satellites, and research will the level of baseline environmental knowledge improve for such new areas.

The issue we are really addressing here is the level of risk we are prepared to accept and how much environmental information is necessary to achieve the level of safety expected by our society. In this regard, standards of vessel design and operation procedures, government regulations and guidelines on operations planning, and management have been defined in order to reduce the risks to an acceptable level.

This leads me to my second point. In the East Coast offshore, world class units are used for year-round operations, and close attention is paid to environmental operating limits where ice conditions and severe weather increase the risk to equipment and activities. These units and the vessels and aircraft supporting them are selected on the basis of design and the extreme winds, waves, and currents which they can expect to encounter. Typically, estimates of 100 year extremes are provided to engineers for evaluation purposes. Confidence intervals are also provided around these data to indicate the quality of the data. Our experience in Canada has shown that the estimates provided for environmental extremes are reliable, and these estimates are successfully applied to the selection of offshore units, as well as to the planning of logistical support for their operation.

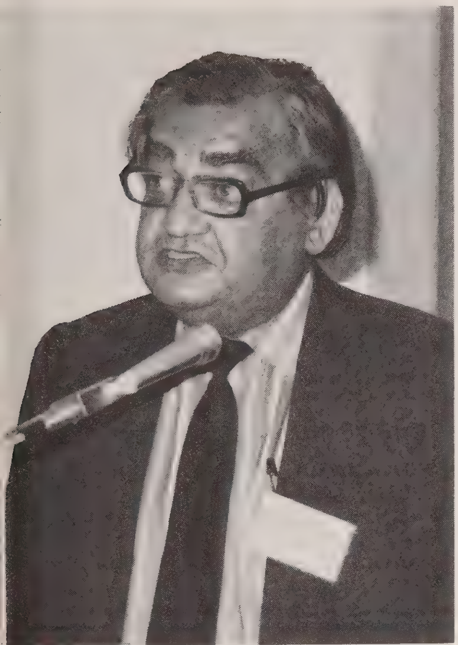
My third point is that day-to-day offshore exploration operations are designed to be conducted with nominal environmental information necessary for their support. Also, day-to-day management decisions are made to minimize risks to operations if environmental information received is erroneous in either degree or timing. Examples of this include management decisions to evacuate units in response to severe hurricanes tracking up the eastern seaboard. A decision to evacuate crews from the Grand Banks or Scotian Shelf requires 48 hours to implement. Clearly, our capability to forecast the tracks of hurricanes about the latitude of the Carolinas must advance by some quantum leap before rig superintendents will take the risks that these storms will not jeopardize the rig or its crew. The same analogy applies to tracking icebergs approaching anchored units on the Grand Banks. In raising these examples, I am not downgrading the need or value of continued R&D on these environmental problems; however, the level of forecasting ability necessary to manage the risk to offshore exploratory activities must be clearly appreciated with each and every study proposal.

Regarding our future efforts to improve environmental information in the offshore, it is both necessary and important to work together to focus our R&D and management efforts. Neither the time nor the resources are available for some of the individual approaches we have seen in the past. Concerning the direction and level of physical marine environmental R&D in Canada, it is obvious that the level of effort has increased significantly in recent years, primarily in

response to offshore hydrocarbon production developments proposed for the Grand Banks and Scotian Shelf. Coordination between industry and government in this R&D has been greatly improved through the Environmental Studies Revolving Funds, the Office of Energy Research and Development and various government study groups. Canadian consultants and universities are also being involved both directly through contracts and indirectly through information exchange and advice. Our R&D efforts are world class, incorporating the latest advances in international technology and information processing and analysis. Also, our research objectives involve short, medium, and long term plans which are, by and large, strongly supported by the petroleum industry.

For my final point, I wish to draw your attention to the problems of how both industry and government will manage the physical environmental data, its processing, analysis, and communication resulting from all the R&D and data collection networks now being planned. At present, various government agencies are responsible for offshore environmental data management. Some of them are struggling to process and make accessible the data being collected. The same is true for other systems coming on stream over the next several years. The problems are related more to policy and financing, rather than to know-how in managing these data. If we are to properly manage the levels of real time environmental data needed to support our future offshore production and exploration activities, it is time to co-ordinate our efforts.

Earlier this year, at the Ocean Issues Conference, the CPA proposed that industry and government begin to address future environmental data communications and management by establishing a task force to address the many and varied problems. Also, solutions to these problems will require the participation of the environmental consultant industry to assure successful resolution. I believe I have highlighted the points which I think are important to our discussions and I appreciate the opportunity to have raised them here today.



Mr. C.A. Bainbridge
Senior Principal Surveyor
Lloyd's Register of Shipping

Mr. Bainbridge holds an M.Sc. in Aircraft Design and Structures and from 1956 to 1970 he worked in the aviation industry as a Structural Analyst in aircraft design. Since 1971 he has been with Lloyd's Register of Shipping, where he is currently Senior Principal Surveyor and Head of the Ocean Engineering Department. In that position he is responsible for structural analysis, plan approval, research and development, and computer analysis relating to all types of offshore structures. Mr. Bainbridge has presented numerous papers, worldwide, on structural analysis of offshore structures.

PAPER B2

Environmental Factors as an Input to Design

ABSTRACT

This paper outlines the role of environmental criteria in the structural design of semi-submersibles. The results of sensitivity studies on many recent units are presented and the effect of National and other code requirements discussed.

BACKGROUND

The forerunners of the present semi-submersibles were the bottom supported space frame structures of the early 1950's. To allow for uneven seabed conditions several of these designs tended towards multiple columns and individual bottom flotteurs. Water depths were of the order of 20 to 30m. These rigs were characterized by a very substantial beam, large freeboard and with limited structure in the maximum wave action area near sea level. In these water depths, the blow out preventers were placed just below the drilling floor and above sea level so all these units were designed with an open drilling slot over the whole depth of the structure at one end. The deck was connected to the matt type bottom structure by a number of columns, several of which, usually at the corners, were of a larger diameter, providing additional buoyancy during tow and deballasting during sit down on arrival on site. There were few or no diagonal bracing members and it is clear that many of these designs would have been suitable only for local tows and not ocean voyages.

The first true semi-submersible the *Bluewater 1* designed to drill in the floating mode began operation in the early 1960's. The majority still maintained the design requirement for the sit-on-bottom mode. These units would drill from about 20m of water in the bottom supported mode to above 100m in the floating mode. The upsurge in offshore exploration, still confined to a few areas of the world, led to a large number of semi-submersibles of different structural configurations becoming available.

Towards the end of the 1960's and early 1970's, the main advantage of the semi-submersible concept (a large stable floating platform) was being recognised and applied to other offshore operations not concerned with drilling at all. One of these first units was the *Santa Fe Choctaw I* an eight column, two pontoon vessel with multiple bracings, built in 1969 as a Crane Barge but soon converted to a Pipelay Barge.

Oil exploration was also now moving on a global scale and the original primary requirement of just moving into deeper waters was being amplified by the need to provide even larger deck load and bulk storage carrying capacity, significant reduction in mobilisation time and the ability to operate under more varied and harsher environmental conditions.

Semi-submersibles were also now being designed and built in a number of countries. Some of the original design criteria like the sit-on-bottom operation were discarded and others like mobilisation time and cost had grown in significance. The configuration reflected this change and generally narrowed down to the twin hull design with several columns and interconnecting tubular bracing members. Though the variations of structural configurations have been reduced semi-submersibles are being used for a larger number of specific offshore applications e.g. heavy lift, pile driving, firefighting, diving support, and early production platforms. For rapid mobilisation and location moves, some of these units are self-propelled for unassisted transit and to improve station keeping on location, others incorporate dynamic positioning.

INTRODUCTION

Against this background, the final design is a compromise based on the importance attached by the designer to the various conflicting criteria. Over the last few years, two additional factors have emerged, continual operation under extremely harsh environmental conditions, in some cases throughout the design life, and the introduction of National requirements incorporating design criteria. This paper outlines the basis of scantling design and the sensitivity of the critical internal stresses to varying environmental parameters e.g. wave heights, periods, directions etc., as well as, how this sensitivity can be influenced by National requirements or codes.

ANALYSIS SYSTEM

To evaluate the stress sensitivity of environmental factors, the "in-house" developed system LOADS (Reference 1) is used. This system (Figure 1) is based on an indirect dynamic analysis technique, in which rigid body velocities (whose structural effects are minimal) are neglected. The structure is considered to be accelerating in all six degrees of freedom from heave position,

where the still water draft has been modified by its dynamic component for each wave condition and phase angle. All external applied forces (wave, current, wind, weight, buoyancy, mooring) are recomputed at this draft position and all remaining out-of-balance global loads (i.e. inertial loads) are balanced within the structure by applying linear and angular accelerations to an equivalent mass idealization of the unit, incorporating both inertial and damping effects.

A fundamental part of this system is to represent the structure as accurately as possible not only for determination of overall global stresses but also, and probably more important, to determine the stresses at the junctions of all the main structural components. A typical overall model is shown in Figure 2 and a close-up of the main joint in Figure 3. Finite element types in this model are as follows:

1. 'BAR' elements; six degree of freedom line elements carrying bending, torsion, shear and axial loads, representing all bracing members, and primary hull girders together with their associated effective width of plating.
2. 'ROD' elements; two degree of freedom line elements carrying torsion and axial load representing minor beams and groups of stiffeners on plated areas.
3. 'QDMEM 1' elements; three degree of freedom isoparametric quadrilateral membrane elements carrying in plane forces only, linearly varying direct forces in two perpendicular planes and shear forces representing the plated areas of the hulls, columns, upper deck box, and bulkheads.
4. 'TRIMEM' elements; three degree of freedom triangular membrane elements, again carrying in plane forces only, direct loads in two perpendicular directions and shear.
5. 'SHEAR' elements; quadrilateral elements carrying in plane shear only and are used as overlay elements representing the shear stiffness of internal plating and secondary structure.

The model shown contains 1010 node points, 405 bar elements, 1490 plate elements and 1420 rods, for comparative purposes, a stick model based on only bar elements is shown in Figure 4.

STATIC STRENGTH

Three main conditions are analysed for overall static strength each related to the particular draft:

1. Transit; at normal transit draft with a specified variable deck load and limited to sea conditions 8 to 12m wave heights or as stated in the operations manual before the unit is submerged to a column stabilized draft.
2. Operating; during the drilling phase and maximum semi-submerged draft with maximum variable load and drilling or crane lift loads, etc., to all sea conditions up to a maximum design specified limit. This limit is determined by the ability of the unit to drill, operate cranes or excessive motions limiting the use of machinery or equipment or airgap restrictions.

When used as an early production platform, the variable deck loads and distribution change and a range of drafts should be considered. Maximum wave heights in the range 14 to 20m are usually specified.

3. Extreme; an intermediate draft at a maximum allowable variable load condition in sea states between maximum operating and extreme design. For unrestricted worldwide use values of maximum wave heights up to 36m have been specified in design.

For each of the above global conditions, the limiting Design environmental criteria specified e.g. wave heights, wind, current, etc., are related directly to the vessel's draft. Over a three year period in the North Sea a drilling semi-submersible was at transit draft 3.4% of the time, 86.7% at operational draft and 9.9% at extreme storm draft. The multi-purpose support vessel *Uncle John*, on the other hand, will have the additional restriction of working close to a platform with no choice to either position or heading. "*Uncle John* normally moves away from its work site when the significant wave height exceeds 5m and there-after stands-by on the most comfortable heading in relation to the sea state", (Reference 2).

Government Regulations tend to focus on the extreme storm conditions while the other two, transit and operational being considered a measure of the efficiency of the unit.

In addition to the global design criteria, three other aspects must be considered for the structure:

1. Non-load related. There are minimum plate thicknesses and stiffener sizes which can be successfully built in any welded marine structure. These minima are specified in Classification Societies' Rules and are based on previous experience, there will be appropriate minima for main structure (pontoons, columns, and upper hull) and for secondary structure including internal frames and bulkheads etc. For structure below the deepest design waterline involving external surfaces, which would be protected by an approved cathodic protection system, the minimum scantlings above are increased, if an approved corrosion protection system is not fitted.

The steel grades are selected for particular areas of the unit with reference to structural importance, service temperature and plate thickness. A typical distribution is shown in Figure 5. The design service temperature is assumed to be the minimum average daily atmospheric temperature (Figure 6). In locations where the design air temperature is below -30°C the use of special low temperature steels at critical areas in the structure may have to be considered.

2. Load-related; 'other loads'. The sources include:

- Structure self-weight;
- Machinery and outfit equipment weights including seatings and foundations etc.;
- Dead loads of stores (bulk) wet and dry, provisions, crew and effects, cargo or other operating loads, which may be carried on the deck or in the tanks;
- Mooring loads, the unit must have sufficient strength to resist maximum pre-tension plus operational/survival surge loads in all lines and locally, each part of the mooring handling gear and foundations for loads up to the breaking strength of a mooring line;
- Towing loads, local back-up structure up to the maximum breaking strength of the specified tow line or towing bitts;
- Ice loadings, the dead loads of ice and snow on deck and sides of the upper structure, the forces on columns and lower hulls due to ice sheet crushing and impact from floes;
- Operational and equipment loads/forces including: drilling derrick crown block, rotary table, set-back, guide line and riser tensioners, service cranes, BOP transfer crane, diving bell transfer and main hoist, wire line D.P. reference, dragway winch, pipelay tensioners, side lay davits, stern latched ramp and stinger (for pipe laying) heavy lift cranes and derricks, fire monitor thrust, production riser loads, accommodation and emergency access bridge or gangway, tanker loading boom or crane and hose, launch and recovery gantry for submersibles etc.;
- Main propulsion thrust and steering nozzle or rudder forces, tunnel thruster forces, D.P. azimuthing thruster/propulsion unit force;
- Helicopter decks, the maximum design landing wheel loads for a particular helicopter over the landing area, manoeuvering wheel loads for the remaining deck area and crash loads for the main support beams and girders;

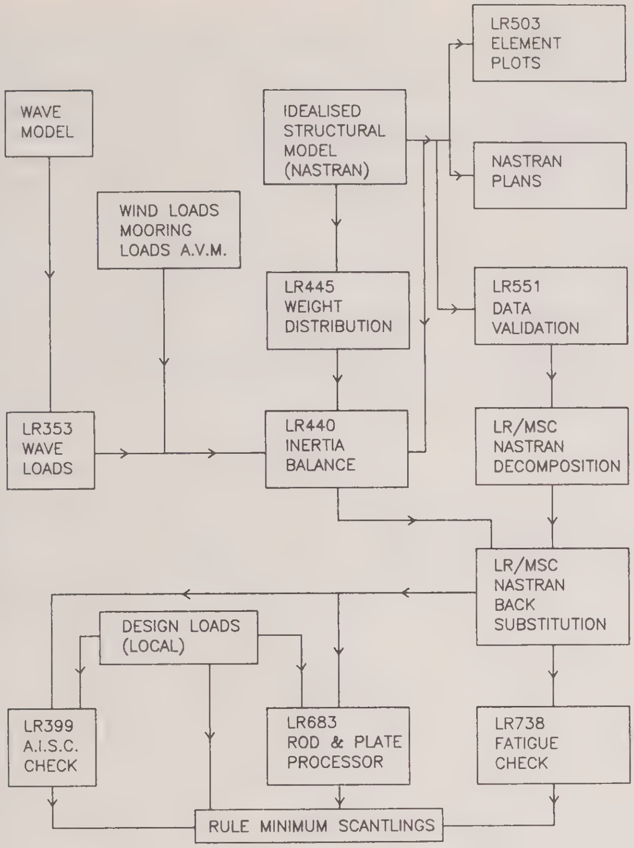


FIGURE 1 "LOADS". Structural Analysis System Flow Diagram

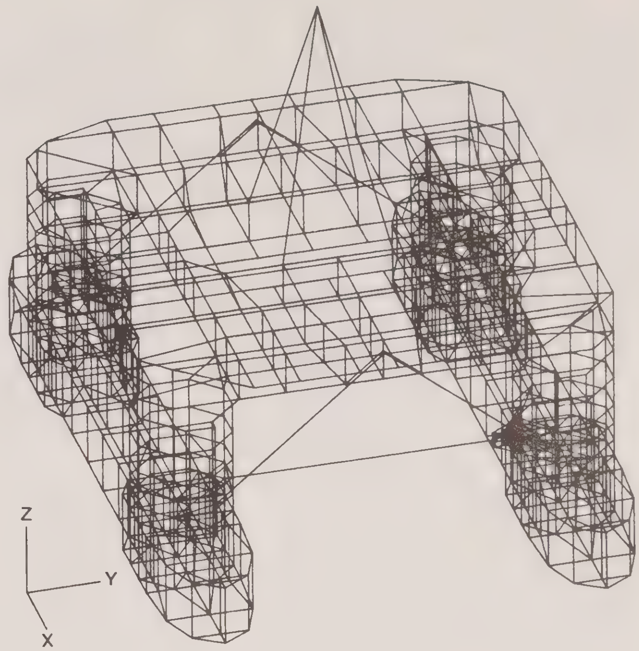


FIGURE 2 Typical global model

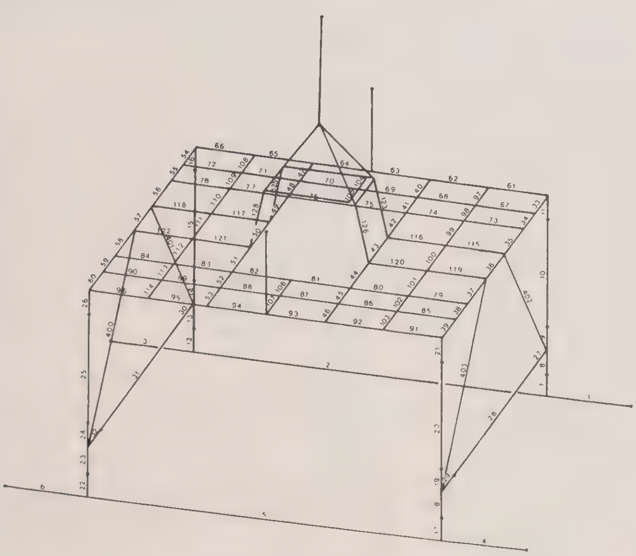


FIGURE 4 A typical stick model

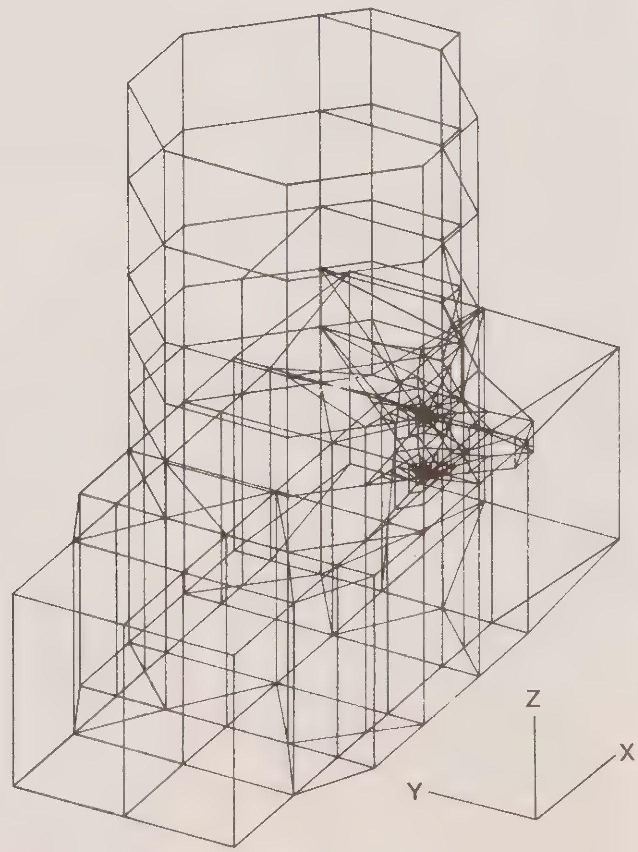


FIGURE 3 Main joint close-up

- Supply boat loads, forces of moored boats where mooring alongside is allowed. Generally for supply boats offloading, impact damage loads on columns and bracings is to be assessed including the effect on the overall structure;
- Deck loadings other than specified deck mounted items for example, crew spaces, walkways, work areas, weather decks, general storage areas have specified minimum pile requirements. Additionally maximum wheel loadings in any area where fork lift trucks or mobile cranes can operate;
- Inertial loadings superimposed on all structure, machinery, outfit, and dead loads based on the accelerations of the vessels' motions in a sea way (obtained from tank tests or equivalent prediction);
- Resonant vibration effects on support structure on certain machinery, propulsion, and operational equipment;
- Live loads from crane reactions, rolling loads etc.;
- Slamming loads and the subsequent vibration cycles on horizontal lower bracings.

3. Pressure-related design. In general, considerable areas of the lower hulls and columns are primarily designed by local scantling requirements of Classification Societies' Rules (Reference 3) due to hydrostatic head from tank overflow, maximum wave or damage water line. The lower hulls usually do not require any increase in scantlings to those designed by hydrostatic pressure except, in some cases, locally in way of the column connections.

Similarly the columns of most of the recent semi-submersible designs have small increases, in the order of a few millimetres over the hydrostatic head designed thicknesses. However, this depends on the relative size of the columns compared to the other rig proportions, if the columns are large like on the pipe-lay barges *Semac* and *Choctaw*, there will be no requirement to increase the basic scantlings while if the columns are small a greater proportion of the required thickness will need to be added by global framework stresses.

- The minimum scantlings of a tank boundary in any location in the vessel are determined by reference to the maximum pressure due to the load head to the overflow vent pipe. The proportion of this load head is determined in the same manner as those set for tank boundaries in the Ship Rules (Reference 4).
- The scantlings of the external boundaries of lower hulls and caissons/columns are not to be less than those for a tank boundary. The minimum head being not less than an equivalent hydrostatic head due to the sea at the maximum design wave crest elevation. In no case are scantlings to be less than those required for a watertight bulkhead as determined below.
- The scantlings of watertight bulkheads are to be determined using a minimum load head to the worst level of the applicable damage waterplane.
- The minimum scantlings for all areas of the unit subject to wave immersion is taken as the actual heads above, where applicable, but not less than 6.0m.

The strength criteria have been outlined above in some detail in order to illustrate that a large majority of the scantlings of a semi-submersible are set by basic considerations from Classification Rules. These can be overall global strength requirements or local design criteria or indeed particular stress cut-offs employed by individual designers, based on their own experience over and above any laid down requirements.

Complex fatigue analyses and spectral analyses procedures are being considered as check conditions for the original basic scantlings (Reference 5). National regulations are also being viewed in the same light as they generally give little or no guidance on acceptable basic scantlings, on the assumption that the unit will be classed.

MOORING

An increasing amount of attention is being paid to the design and analysis of positional mooring systems. As the mooring system loads are directly related to environmental conditions and vessel motions (which are also a function of the sea state) it is important that the basic design environmental criteria are realistically chosen. Of necessity, the design conditions are, in reality, envelopes of environmental criteria in association with operational limitations combined with acceptable Factors of Safety. Underestimation of the environment or particularly the way in which it combines, leads to excessive motions, inadequate safety factors and possible, costly failure, in addition to the general loss of operational time. Over-conservatism, on the other hand, adds weight and costs from larger and longer mooring lines, bigger winches etc. and perhaps reduced deck load carrying capacity. There are two main design conditions specified:

1. Survival represented by the 50-year storm. The vessel will be expected to remain on location, but with the drilling unit disconnected from the seafloor, large values of excursion can be tolerated. Design Criteria for this condition consist only of restriction of maximum tension in the mooring lines with a minimum factor of safety of 2.0 based on the breaking strength of the line. The maximum line tension is calculated for concurrent colinear combinations of design wind, design wave, design current in the most unfavourable heading and with the appropriate vessel motions and given water depth. Typical values in the North Sea are a sea state with a significant wave height 16m, 14 second period; maximum wave height 30m, 19 second period; a 1.5m/s current and a wind speed of 50m/s.

2. Maximum operating based on the combination of wind speed, wave height/period, current, at a water depth and offset limited to the value up to which the drilling unit can still sustain operations. In addition to heave the offset or total horizontal displacement from the well bore is another limiting factor in regulating operational activities, to prevent damage to the marine riser and BOP Stack. Operational criteria can vary with the characteristics of the unit and its equipment, however, typical values in the North Sea are a sea state with a significant wave height 7m, 9.5 second period; maximum wave height 13m, 12.0 second period; a 0.5m/s current and a wind speed of 20m/s at the specified water depth range and a maximum excursion up to 6.0% of the water depth. Sub cases may also be considered 'waiting on weather' with a larger offset and a harsher environmental combination. With the offset limitations above, a minimum safety factor of 3.0 must be achieved based on the maximum line tension against the breaking strength.

In the North Sea, the Norwegian Maritime Directorate has introduced "damaged" conditions, i.e. failure of a single line with both operating and survival above but associated with the reduced safety factors of 2.0 and 1.4 respectively. For semi-submersibles used as accommodation near fixed platforms, the latter safety factor is increased to 2.0 and applies specifically to the lines maintaining separation in the 'stand-off' position.

As stated previously, mooring line tensions and anchor loads are directly related to the motion characteristics of the vessel in a given sea state. The highest static loads occurring when the unit is at its greatest distance from its tensioned position. The pattern of motion comprises three separable effects:

1. A steady displacement from the origin to a mean position. This shift is caused by the wind, current, and mean wave drift forces.

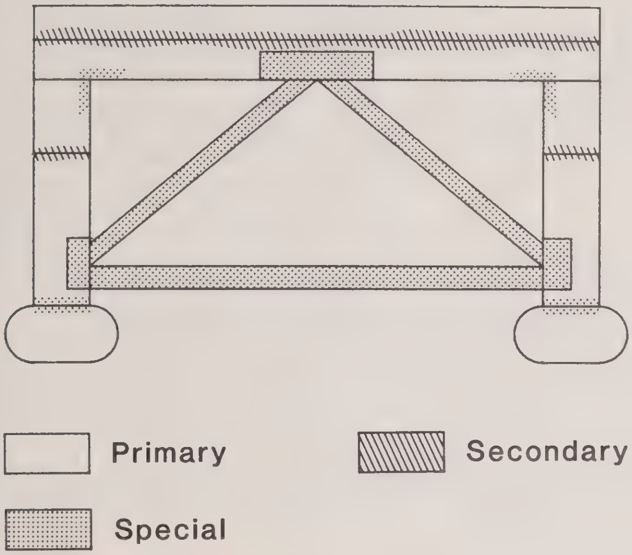


FIGURE 5 Typical steel categories

STRUCTURAL CATEGORY	REQUIRED STEEL GRADE	MAXIMUM THICKNESS (mm) FOR VARIOUS DESIGN TEMPERATURES 0 °C	−10 °C	−20 °C	−30 °C
SECONDARY	A	30	20	10	X
	B	40	30	20	10
	D	50	40	30	20
	E	50	50	50	50
	AH	40	30	20	10
	DH	50	50	45	35
	EH	50	50	50	50
PRIMARY	A	20	10	X	X
	B	25	20	10	X
	D	35	25	20	10
	E	50	50	50	40
	AH	25	20	10	X
	DH	45	40	30	20
	EH	50	50	50	40
SPECIAL	A	X	X	X	X
	B	15	X	X	X
	D	20	10	X	X
	E	50	45	35	25
	AH	15	X	X	X
	DH	30	20	10	X
	EH	50	45	35	25

FIGURE 6 Low temperature steel grades

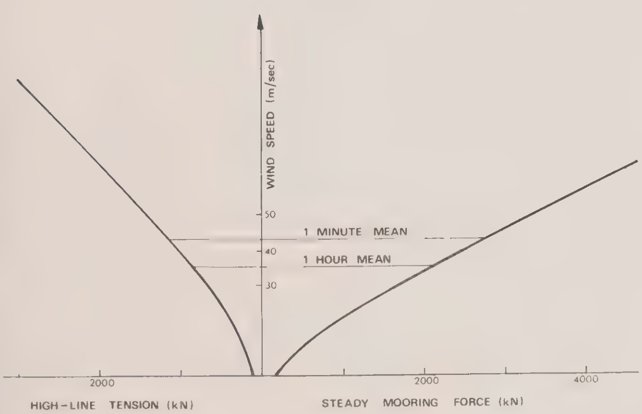


FIGURE 7 Effect of wind averaging speed

SEMI-SUBMERSIBLE

DESIGN CRITERIA WORLDWIDE

STATIC STRENGTH

DRAFT	WAVE HT(m)	ALLOWABLE STRESS
TRANSIT	8 – 12	0.6 Fy
SURVIVAL	30 – 36	0.8 Fy
OPERATIONAL	14 – 20	0.6 Fy

FATIGUE 20 YEARS MINIMUM

DRAFT	WAVE HT(m)
OPERATIONAL	2 – 12

WIND UP TO 110 KNOTS

CURRENT UP TO 2.5 KNOTS

FIGURE 8 Design criteria

2. A low frequency oscillation about this new mean position. This is the result of a slowly varying drift force, principally wave drift but with some wind influence.
3. Surge or sway oscillations at wave frequency. These, first order wave motions, have amplitudes which vary directly with wave amplitude.

This dependence on both environmental forces and the forced displacements makes sensitivity studies only relevant to a particular unit. Wind tunnel testing, wave tank models, and field investigations, analysing recorded mooring line tensions have been used for improving our knowledge of the individual parameters, and fully dynamic mooring analysis packages are being developed. The current state of the art analysis procedures, design envelope conditions, and factors of safety reflect operational experience. However, while there is some degree of standardisation of approach to the selection of the design envelope and to mooring line analysis procedures, there are anomalies. For example, the recently issued API RP 2P (Reference 6) recommends the one minute mean wind velocity as the basis for wind force calculation, whereas the Norwegian Maritime Directorate regulations (Reference 7) allow the use of the one hour mean wind speed. An illustration of the apparent differences, in mooring load and line tension, in the same environment, but with different wind averaging periods used, as the basis for calculations is shown in Figure 7. On this particular rig, as the one minute wind speed is some 17% higher, it generates 37% more wind force and adds 30% to the steady line tension.

It must be noted here that success of the mooring system depends not only on operation within the design envelope but also on the maintenance of the integrity and reliability of all the individual components.

A word of caution, introduction of new criteria, seemingly more onerous e.g. one line failure, leads to a more rigid mooring system. This trend increases the loads produced by currently considered "second order effects", such as slow drift oscillations. The long term possible fatigue problem has yet to be addressed.

STATIC STRENGTH SENSITIVITY STUDIES

All the results presented in this section have been obtained from the analysis of actual platforms satisfying the design criteria shown in Figure 8, and classed with the Society. Though there will be variations with different designs, the trends indicated are representative and have been confirmed by numerous analyses on several new semi-submersibles.

Wind

The structural implications of wind are not significant. For a typical vessel, wind forces lie within the range 250 to 500 tons for a velocity of 50m/s with head and beam on forces approximately equal.

Wave Height/Direction

The variation in nominal stress with wave height and direction for a transverse lower bracing member is shown in Figure 9. In each case a constant wave height/wave length ratio is maintained though the trend is similar for other ratios, the draft is kept constant at its operational value of 18m. The increase in member stress due to wave approach angle is clearly demonstrated. The nominal stress due to a 20m wave head on is roughly the same value produced by a 3m wave beam on, conversely there is a 46% increase in stress for a 20m wave from head on to a beam on approach. A diagonal lower bracing member shows different characteristics (Figure 10). In this case maximum nominal stress occurs for a wave approach angle near 45° and the stresses produced by a 20m wave from this direction are 65% greater than both beam and head on, which are roughly the same.

Wave Height/Period/Draft

In this investigation a transverse bracing in one of the newest semi-submersibles is considered. Only the critical beam on approach angle is used.

The maximum design wave height for transit draft is 10m, for operating draft 15m, and for survival draft 36m. With these imposed cut-offs the calculated nominal brace stresses at each of these drafts is shown in Figure 11. A wave height/wave length ratio of 1/10 has been used for wave heights up to about 24m varying to 1/14 for the maximum wave height of 36m. The maximum stresses produced at transit and operating draft are roughly the same and lower than that produced by a 20m wave at survival draft. In fact, normalizing these axial stresses with respect to wave height indicates similar curves for survival and operating conditions, as in both cases the brace is submerged. At transit draft higher levels of axial stress/wave height are produced. The brace is now exposed and there is a larger associated moment arm (Figure 12).

Some authorities allow increased stresses up to 0.8 x yield stress for all conditions involving environmental loads independent of draft. On this basis, it is obvious that the stresses at survival draft will be the critical design criteria for strength scantling assessment. On the other hand, it has always been our policy that stresses at transit and operational draft be restricted to the normal 0.6 x yield stress and the increased one and one-third factor only applicable to survival draft, consistent with the fact that a normal rig should only spend less than 10% of its life under extreme storm conditions at survival draft, the rig staying at operational draft as long as possible. Incorporating the increased allowable only for extreme storms at survival draft, the design criteria changes and strength scantlings will be determined by operational cases limited to 0.6 x yield stress. The dotted line in Figure 11, represents the survival condition reduced by 0.6/0.8 factor for comparison purposes.

It must be stated that the transit and to a lesser extent the survival conditions shown are conservative as one would expect the rig to be head on at the limiting wave conditions for each draft.

FATIGUE SENSITIVITY STUDIES

The fatigue life of welded steel structures is dependent solely on the applied stress range and the corresponding number of applications. For any point on the structure, the stress range will depend on draft, wave height, wave period, orientation, stress concentration factor. With a wave exceedence curve for the area of operation, a stress exceedence curve can be computed. The estimated fatigue life is then evaluated based on the Palmgren Miner cumulative damage law using an S-N curve appropriate to the weld detail. It is obvious that the environmental climate plays an important part in this assessment.

Wave Periods/ Direction

For a similar transverse bracing member as used previously, the stress ranges were evaluated for 5 wave heights, 2m, 4m, 6m, 8m, 12m with mean periods as shown in Figure 13 and a stress range exceedence curve computed (Figure 14). Again waves from head on having little effect. Using the U.K. Department of Energy S-N curves, the fatigue damage and fatigue life was estimated (Figure 15). The whole exercise was then repeated, this time assigning a range of periods to each wave height. The results in fatigue terms were similar, the mean period giving conservative lives. The convex shape of the stress range exceedence plot should also be emphasized.

In the conventional spectral analysis, the wave exceedences are computed from a Rayleigh distribution function. This leads to a linear variation of wave heights and excee-

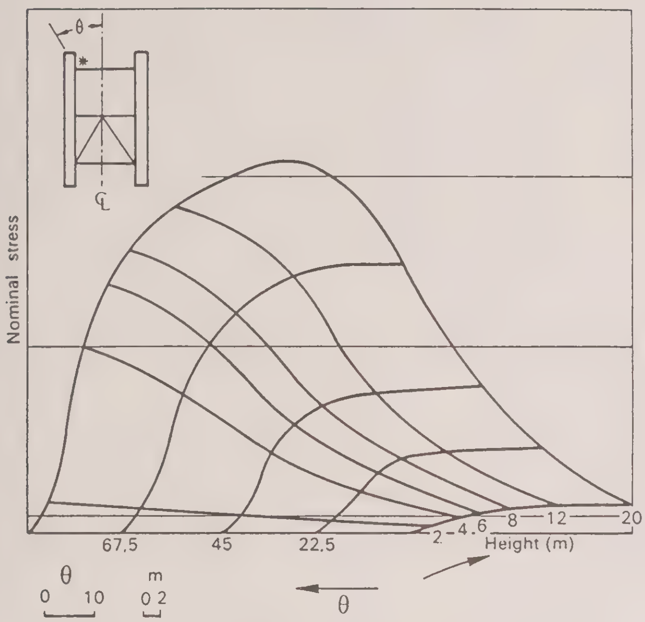


FIGURE 9 Nominal stress variation

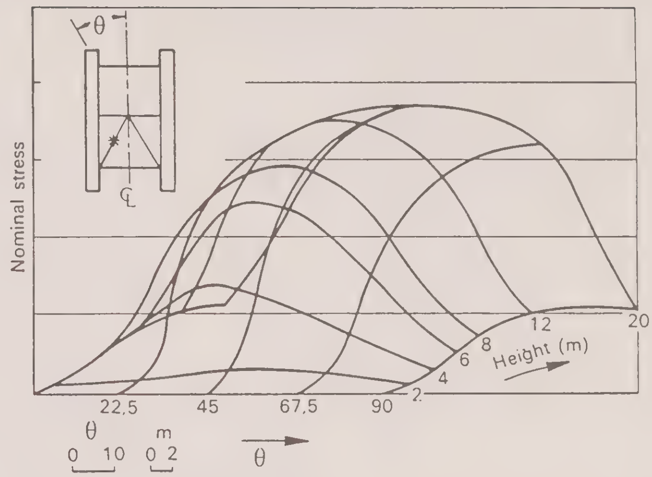


FIGURE 10 Nominal stress variation

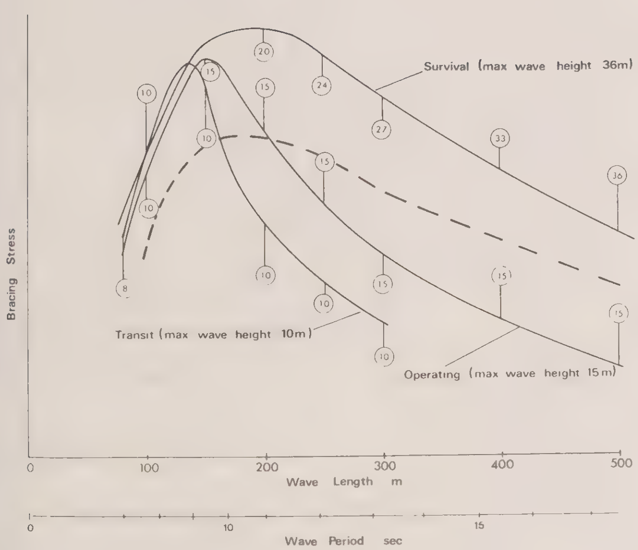


FIGURE 11 Maximum brace stresses

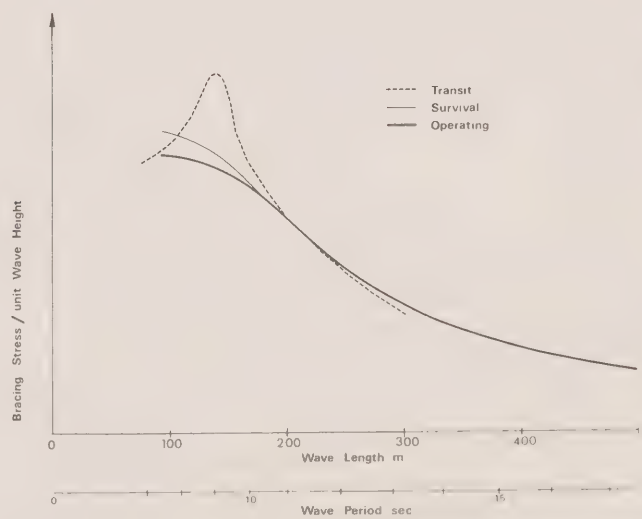


FIGURE 12 Normalized brace stresses

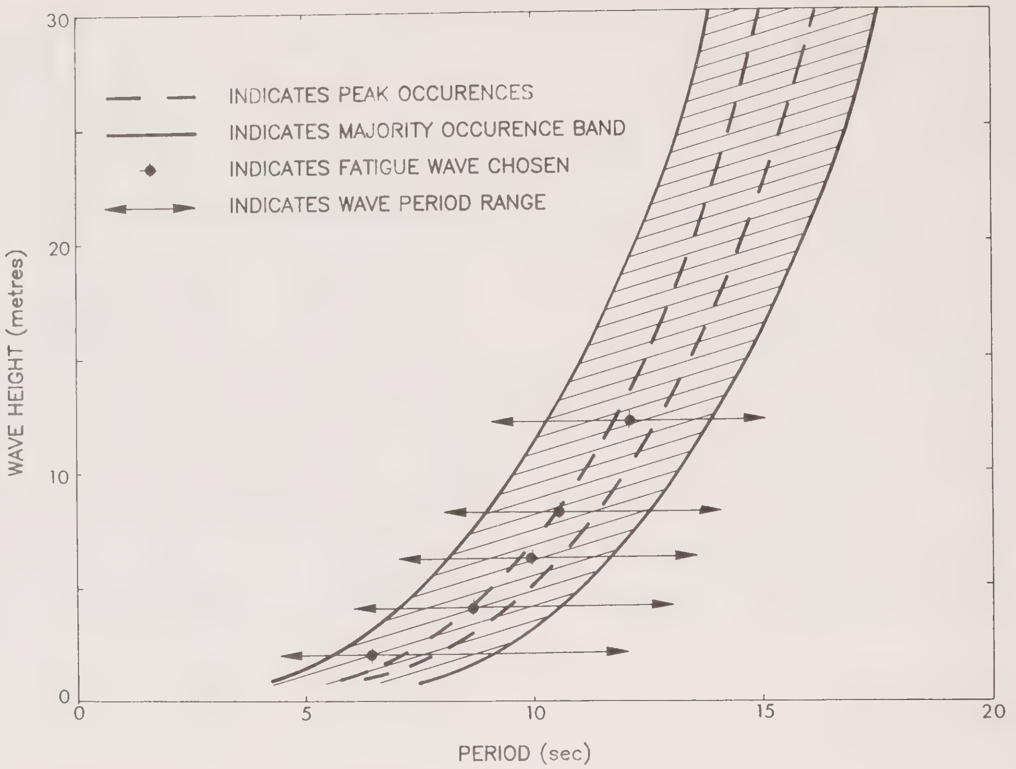


FIGURE 13 Wave height/period distribution

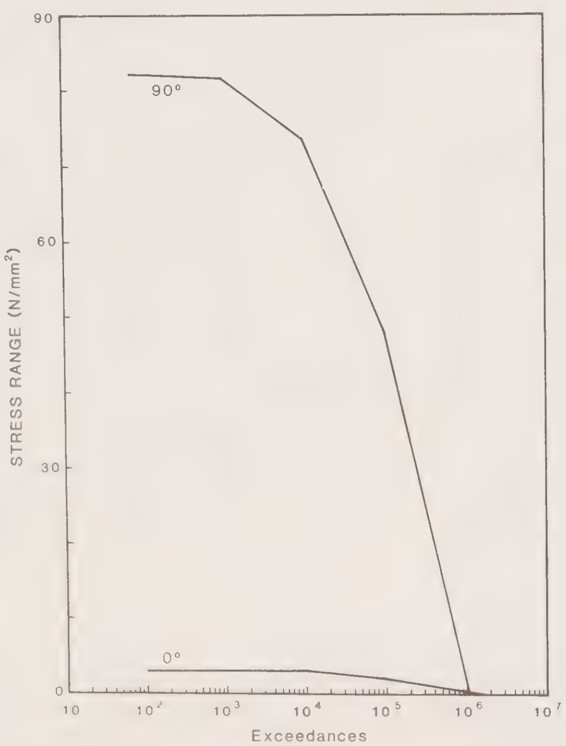


FIGURE 14 Typical stress range exceedence

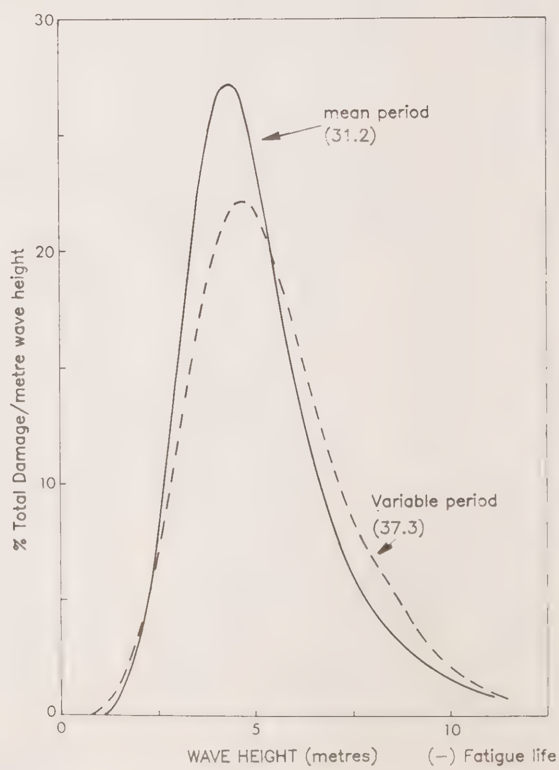


FIGURE 15 Fatigue damage

dences on a log-linear plot. With the further assumption of a linear relationship between wave height and stresses, the stress range exceedence plot will also be linear in contradiction to that evaluated previously. The method is used because of its computational simplicity but leads to inaccuracies if the stress and wave height relationship is not linear as is the case for semi-submersibles. The following procedure (Reference 8) is therefore used in evaluating the stress range exceedences (Figure 16). The sea states are defined by the scatter diagram of significant wave heights and zero crossing periods. An envelope of stress range transfer functions represented by stress range per unit wave height versus wave period, together with the relation between wave height and period given by the wave steepness are then used to compute the stress range spectra. The number of stress cycles corresponding to a given wave height are evaluated by summing the cycles from a Rayleigh distribution function of wave heights only. The stress levels and their occurrences are sorted to obtain the stress range occurrences summed to obtain the exceedence curve, which verifies the convex shape obtained in the deterministic method. This is an important point because the shape of this curve relative to the allowable S-N curve determines the sea states that cause most damage. A typical annual damage "scatter diagram" is shown in Figure 17, which indicates that the most damaging sea states for a semi-submersible are in the of region 6 to 10 seconds zero crossing periods and significant wave heights of 3 to 6 metres based on a North Sea scatter diagram. This includes the fact that the number of occurrences of these sea states in the wave scatter diagram have already been accounted for in the damage summation. It is also considered realistic to introduce a lower cut off level in the wave scatter diagram to about 2m wave height, as the characteristic dimensions of the structure are larger than the wave particle orbital path for small wave heights leading to inaccuracies in load estimation and the stress levels are very low.

S-N CURVES

Given the same stress range exceedence curve for a critical area in the semi-submersible the computed fatigue life and damage distribution can vary with published S-N curves, for example, the U.K. Department of Energy/B.S.5400 the Welding Institute (Reference 9) or American Welding Society (Reference 10) for the same welding detail.

The relative damage distributions for stress concentration factors of 1.0, 1.4, and 1.8 are shown in Figure 18 together with the calculated fatigue life. Based on the A.W.S. 'F' curve, no damage occurs with the three S.C.F.'s for all wave heights below 5m and the total damage is only a small fraction of the Department of Energy 'W' curve, where also upwards of 40% of the damage occurs below 5m wave heights.

Detail Design

Experience has shown that fatigue cracks start and propagate from areas of high concentration factors either at joints or along the bracings. Though it is preferable to avoid all unnecessary attachments, some are essential like butt welds, anode connections etc. The lower bracings of a semi-submersible are subjected to a complex stress range pattern due to overall racking, twisting, and splitting of the pontoons and columns caused by the passage of each wave. The maximum stress range for axial and bending loads along a 'clean' bracing for three different wave approach angles is shown in Figure 19. It can be seen that the quartering seas produce the maximum stress range over 30% of its length nearest each column, the central 40% being critical for beam on seas. Using stress concentration factors obtained from acrylic model tests for typical details (Figure 20), several parametric studies with different North Sea exceedence curves were conducted (Reference 11) and the results for acceptance of details along a brace are presented in Figure 21, including the effect of maximum design brace stress. Thus, for example, for a design nominal stress cut-off of 0.7 Fy in the brace, only a ground butt weld detail would be acceptable over the entire length, a smooth blended stiffener end detail would only be acceptable over the middle 80% of the bracing, all the other details would be unacceptable. At the other extreme, all the details would be acceptable if a limiting design brace stress of 0.4 Fy was used.

OPERATIONAL HISTORY

It can be seen that during the design phase, several assumptions have to be made about the environmental conditions a platform is likely to be subjected to during its life. This is further complicated by the number of different areas in which a platform is likely to operate. One of our classed rigs has already made over eight transatlantic crossings and more recently, the *Benreoch*, built in Korea, was towed to New Zealand for a short season of drilling after which, it will be dry towed to European waters for further operations.

To quantify actual operating conditions, the Masters' logs of several semi-submersibles are being continuously investigated (Reference 1). As an example, the first six years of records made every six hours on *Pentagone 84* is shown in Figure 22. Early calibration of the wave heights indicated a best fit of H (significant) = 0.7 H (visual) and this factor has been used throughout. A typical annual cumulative percentage rosette is shown in Figure 23. The significant wave height bands have been increased in 2m intervals from zero. Since the platform headings were also recorded, the right rosette shows the percentage occurrence of the sea states relative to the platform axis. In the example shown, *Pentagone 84* was operating in the Channel and the majority of the seas approached from the West. Since the Platform was also oriented towards the West during this period the sea states were predominantly head-on. From these rosettes, over the whole operational life, exceedence curves relative to the platform have been created, the wave data being grouped in terms of height, period, and direction.

For each wave height and direction category the percentage time of occurrence was then converted to numbers of waves and the ratios of numbers of waves in each height is shown for two directions relative to the Platform in Figure 24.

Percentage ratios for head on seas range from 17% for waves under 2m height to 40% for waves above 12m. These percentages and their subsequent structural effects would be vastly different under a different set of operational headings, bearing in mind, that beam on waves can be up to 30 times more fatigue damaging than the same waves head on for certain critical bracing members.

CONCLUSIONS

1. The fundamental design objective of a semi-submersible is to provide the offshore industry with a large stable, yet mobile, platform from which drilling and other operations can be safely, efficiently, and economically accomplished. As such, the final design must be a compromise to the various conflicting criteria, of which environmental climate is one.
2. Even under similar environmental conditions, the structural effects vary with operational procedures.
3. The calculated stress sensitivity of critical parts of the structure to particular aspects of the environment can also vary with National requirements and Codes of Practice.

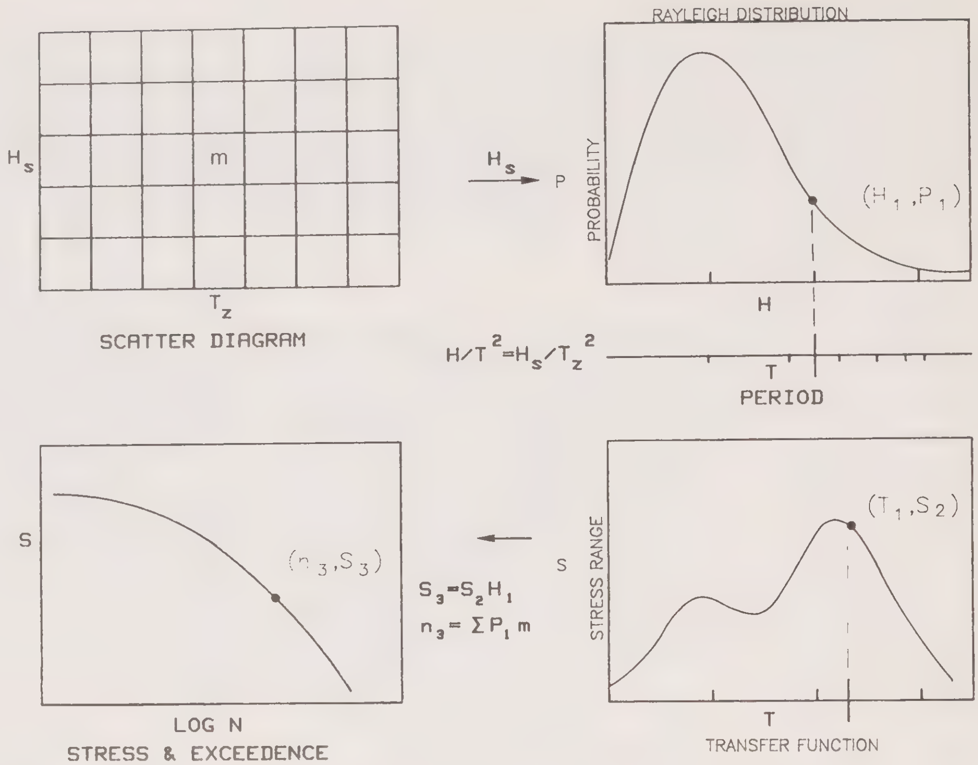


FIGURE 16 Modified spectral analysis

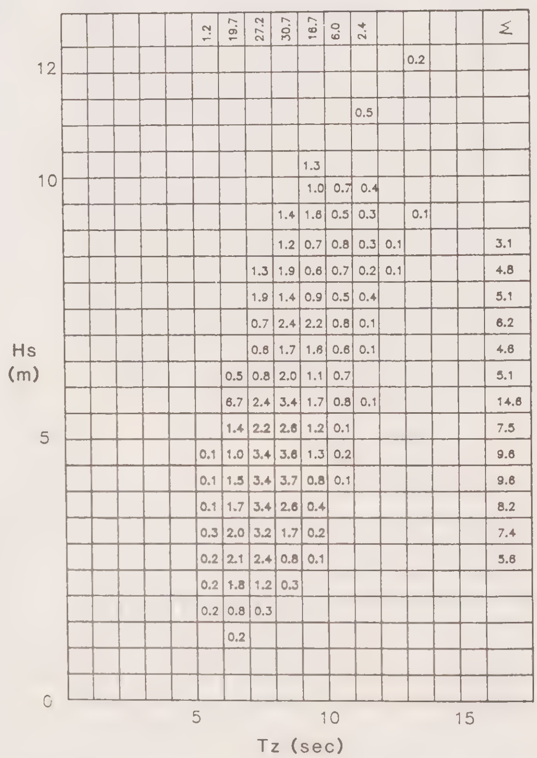


FIGURE 17 Annual damage scatter diagram

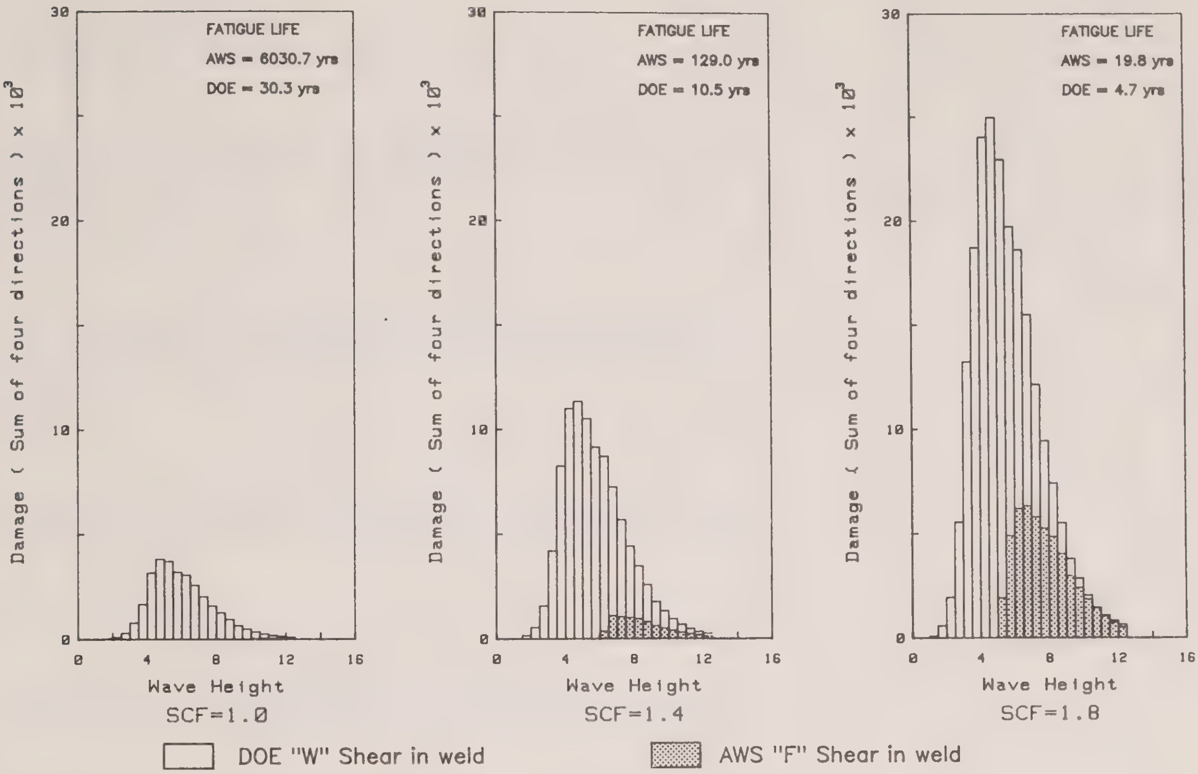


FIGURE 18 Fatigue damage distributions

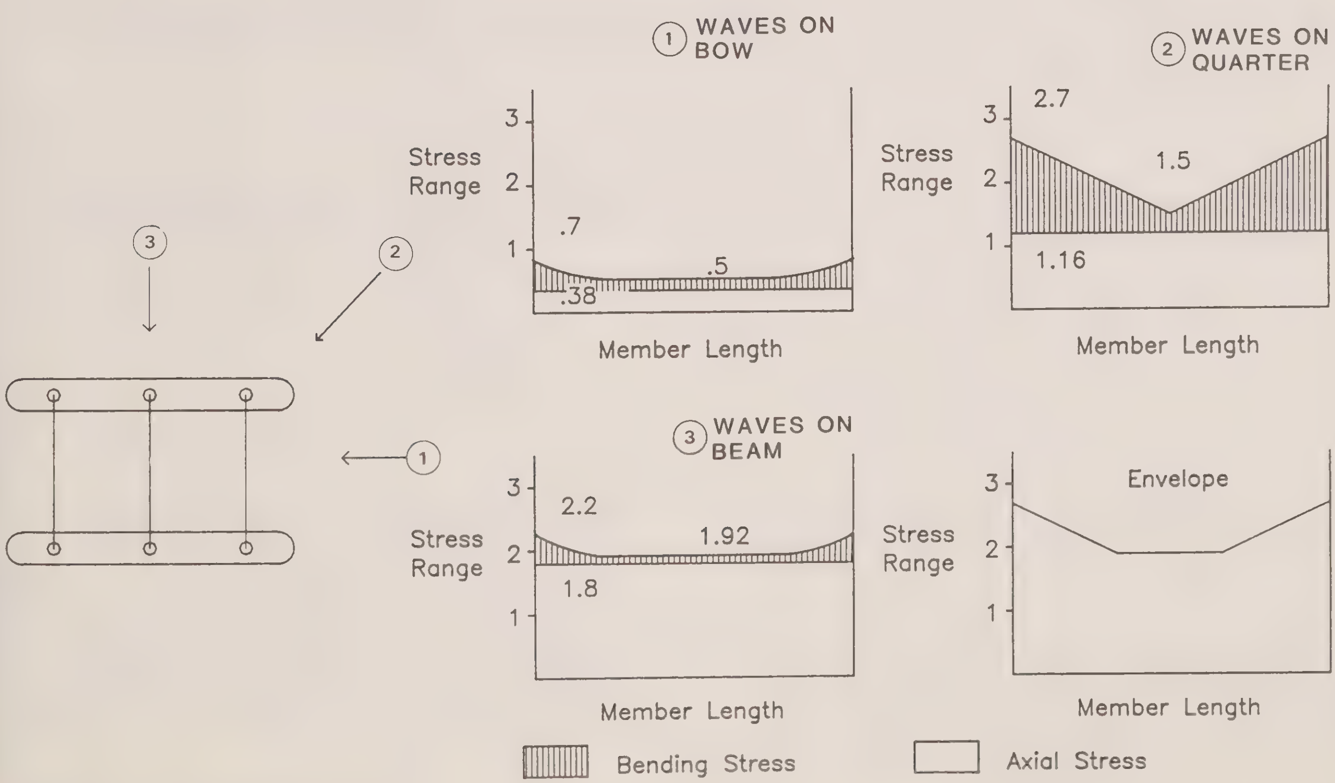


FIGURE 19 Stress range distribution

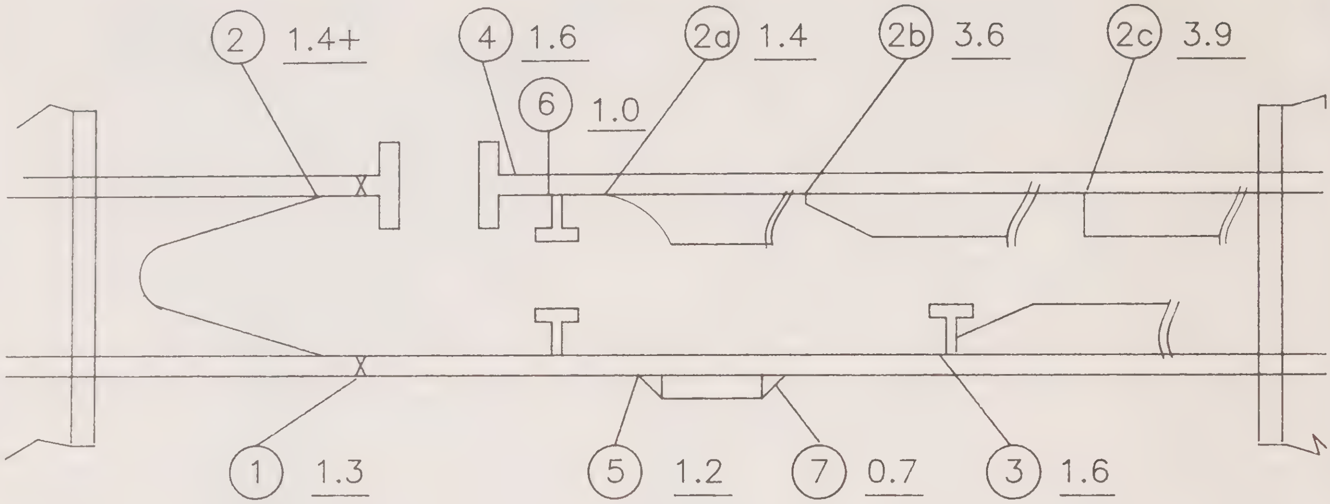


FIGURE 20 Stress concentration factors

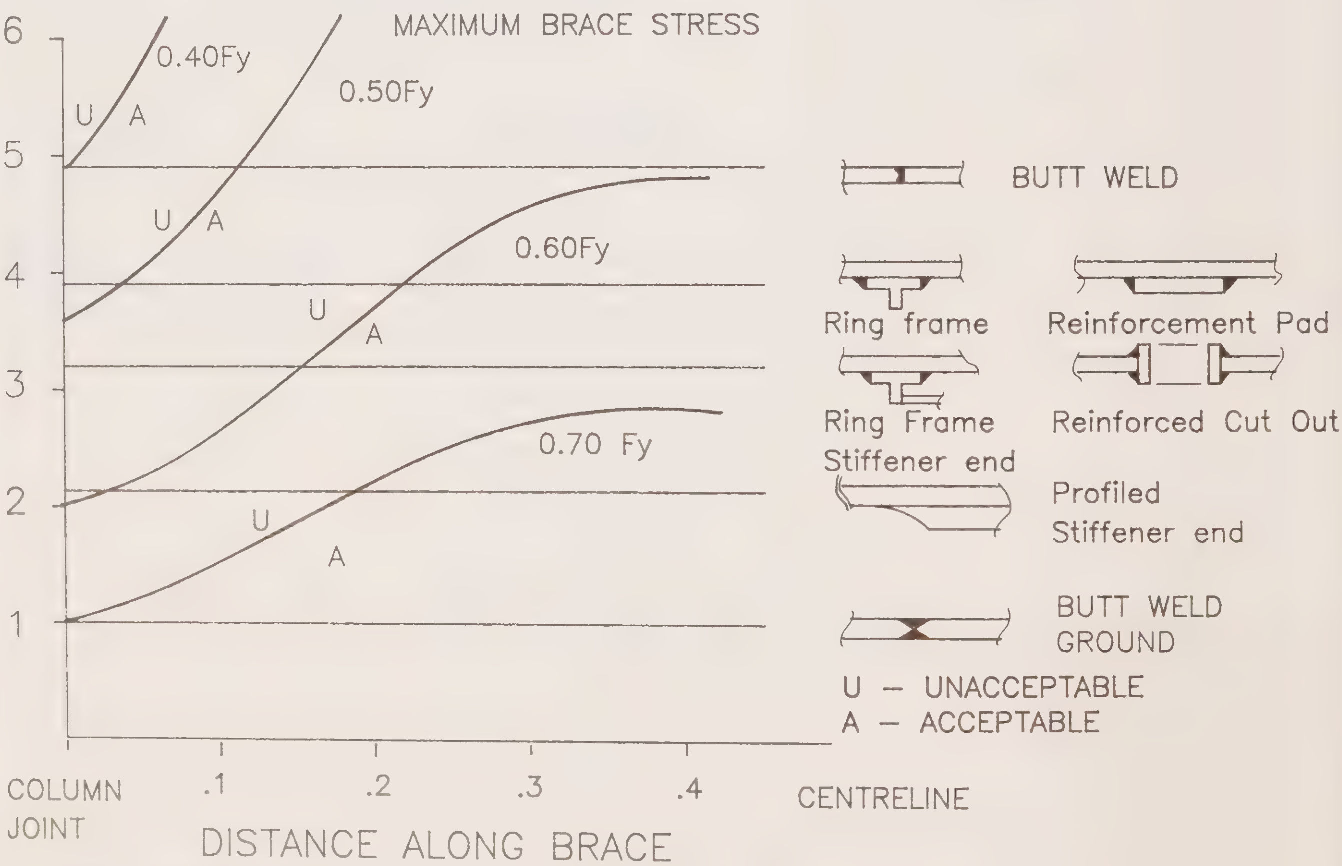


FIGURE 21 Detail acceptance

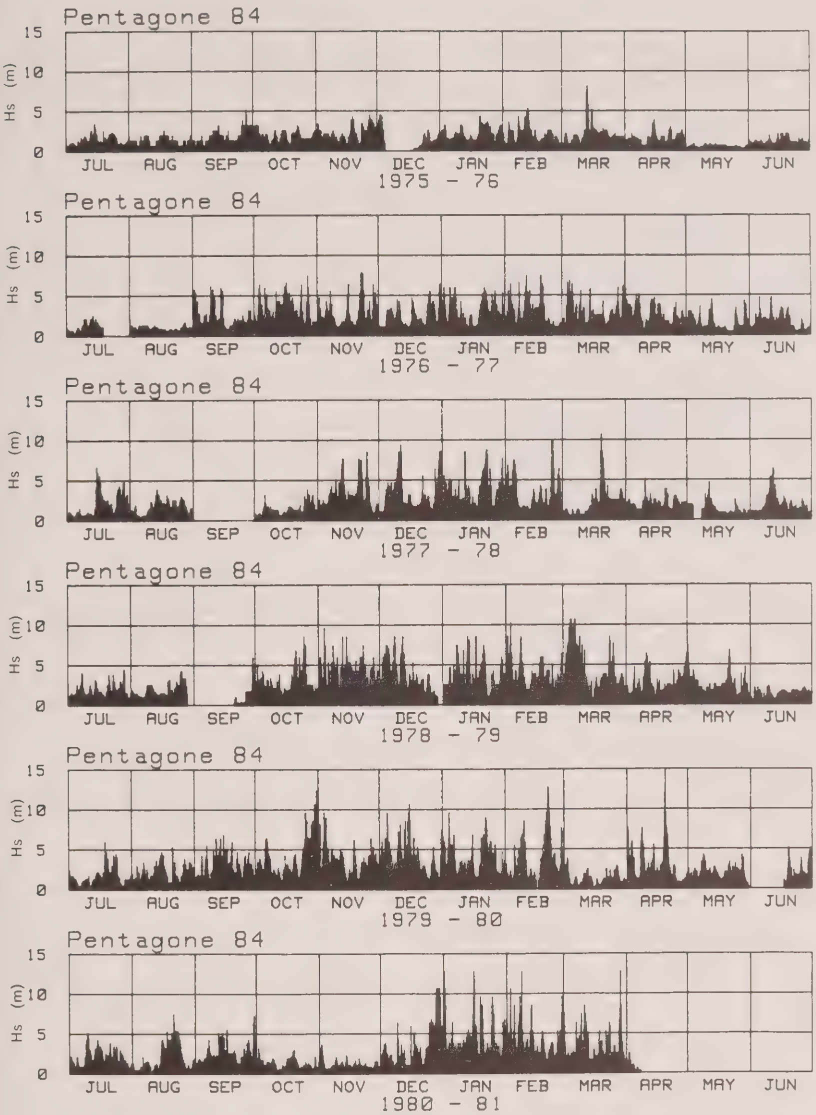


FIGURE 22 Seastate history

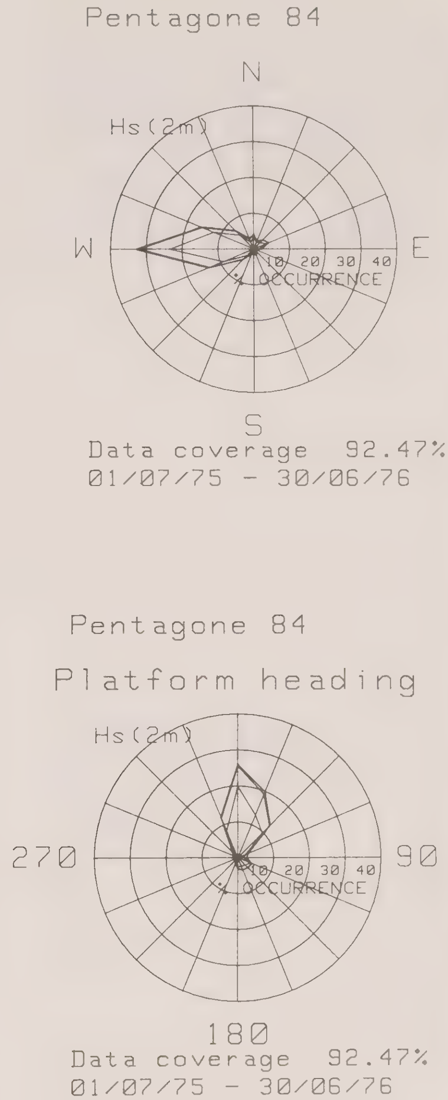


FIGURE 23 Annual rosettes

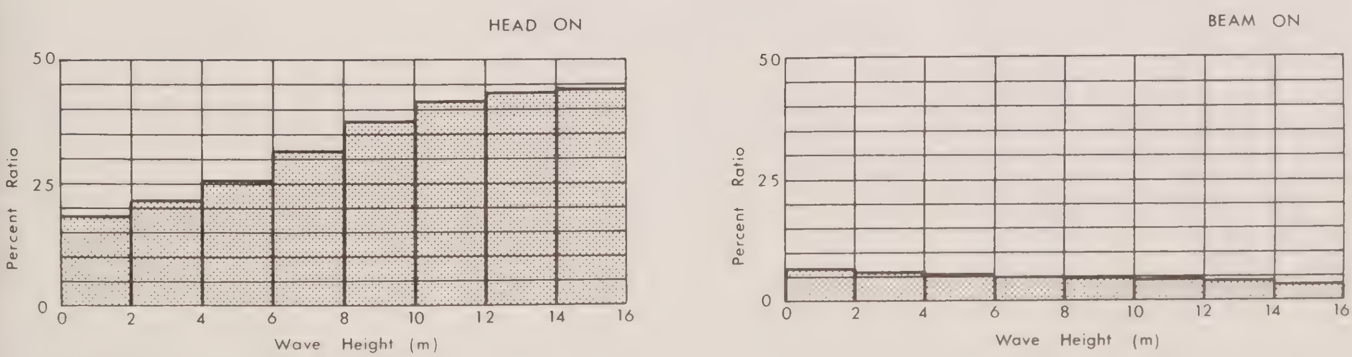


FIGURE 24 Wave directional distribution

ACKNOWLEDGEMENTS

The author is indebted to the Committee for permission to write this paper and to his colleagues for their help in its preparation.

The opinions expressed in this paper are the author's and are not necessarily the policy of Lloyd's Register of Shipping.

References

(1) Design and Operation of Semi-Submersibles. C.A. Bainbridge. R.I.N.A. Symposium on Offshore Engineering, November 5, 1981.
(2) *Uncle John* a semi-submersible multipurpose support vessel. J.M. Houlder CBE. Institute of Marine Engineers Vol. 94 1981, Paper 18.
(3) Rules and Regulations for the Classification of Mobile Offshore Units. Lloyd's Register of Shipping, 1984.
(4) Rules and Regulations for the Classification of Ships. Lloyd's Register of Shipping, 1984.
(5) Designing the *Trosvik Bingo 3000* K. Haslam. *The Naval Architect*, March 1981.
(6) The analysis of spread mooring systems for floating drilling units. American Petroleum Institute. API RP 2P, First Edition January 1, 1984.
(7) Regulations for Mobile Drilling Platforms 1983. Norwegian Maritime Directorate.
(8) A parametric investigation of fatigue of semi-submersibles. OSG/TR/84004. Dr. R. Nataraja. July 1984. Internal Report (to be published).
(9) Offshore Installations. Guidance on the Design and Construction. Her Majesty's Stationery Office.
(10) Structural Welding Code – Steel. American Welding Society ANS/AWS/D1. 1-83.
(11) Design Considerations of Permanently Moored Semi-Submersibles. C.A. Bainbridge. Fifth South East Asia Conference, February 1984.

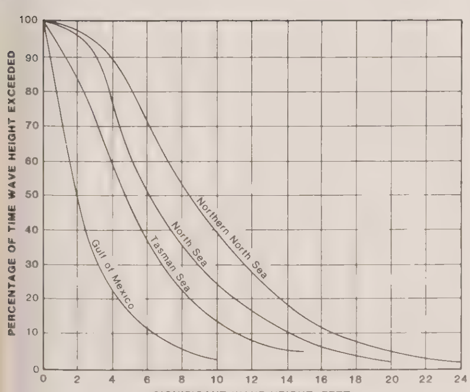


FIGURE 1 Wave height exceedance for four offshore areas

COMMENTARY ON PAPER B2

B.P.M. Sharples
President
Noble, Denton & Associates

I wish to thank the Royal Commission and the author for providing me the opportunity to add any comment on this paper and the theme of Environmental Factors in Design.

The author is to be congratulated for compiling one of the most comprehensive and interesting papers on analysis of semisubmersibles and for identifying at least some of the conflicts facing designers of these complex structures.

There have been a lot of advances made in the last ten years in the analysis techniques of semisubmersibles; there is still a lot of progress, however, to be made. We have seen in this paper how computer programs can develop the motions of a semisubmersible and how you can use this to derive forces at the joints. Most of the available programs are based on the same hydrodynamic equations but the input of damping coefficients can change the results and thus you can get different answers. Most programs have been benchmarked against at least some model tests, but even these vary, depending on in which wave tank the model tests were performed. Some recent analysis done on semisubmersibles, using the Diffraction Theory as opposed to the Morrison Technique, has shown discrepencies of up to 20% in the forces. Wave induced heel is another area of some controversy which has shown up in model tests but so far very little evidence exists of its being a problem for full scale units (1). The observation to be made here is that this is the state of the art, and research and development is constantly revising the analytical tools we have available.

In 1972 I was on board one of the first semisubmersibles in the North Sea to suffer fatique damage. The initiation point for the fatigue crack in that case was a poor detail on an access manhole into a bracing member. Industry response to this event, as is often the case in the offshore industry, was excellent, and as a result of this and one or two other incidents, we today have comprehensive means, as outlined by Mr. Bainbridge, of evaluating these fatigue effects. Ten to twelve years ago this was generally not done in the offshore environment, though some of the technology existed in the aircraft industry. Once this very sophisticated type of analysis and design check is complete, it is important to be aware that there are still problems in operating these units with respect to environment. Let me first say that perhaps the best way for owners, insurers, and government agencies to assure themselves of a quality design to good engineering standards is to have the design checked by a classification society and to have the unit built to a classification society standard.

Certain assumptions underlie any analysis, and it is necessary to make sure the assumptions remain valid at the operating location. Suppose we have a semisubmersible built to operate in the North Sea. As Mr. Bainbridge points out, we could be looking at 98 foot maximum waves in, say, a 19 second period. At a particular location in offshore Canada, a 105 foot wave with a 14 second period may be more appropriate. Since we have seen how wave height and period can vary the forces, we need to consider the effect of these changed environmental factors on the unit.

Mr. Bainbridge directed us to the wave height frequency scatter diagram used in evaluating the fatigue life of a semisubmersible. The distribution of wave heights does vary in different parts of the world. As Figure 1 indicates (2), a semisubmersible checked out by this method for the Gulf of Mexico would not necessarily have a suitable fatigue life in the North Sea or Canadian East Coast environment.

My main point is that when a rig designed on certain environmental assumptions moves to a new area of operation, it is necessary to check those assumptions against the conditions for which the calculations were done.

An example of this is when the first semisubmersible was towed to Hudson Bay. Elf Aquitaine chartered the semisubmersible platform *Pentagone 84*, owned and operated by Forex Neptune Drilling Company, to drill two wells in the summer of 1974. Prior to the tow from the North Sea, a study was carried out to determine the likely ice conditions to be met in the Hudson Strait when it was declared open for navigation. On the basis of this study, the five footing pontoons of the unit were reinforced at the waterline to withstand ice impact over an area of 120° each side of center line from forward. On the inward passage in June, seventenths multiyear ice cover was met in the Strait together with ice floes of an estimated 15,000 tonnes which were impacted at slow speed. On the return trip in October no ice was encountered.

Lest we spread too much alarm, let me assure you from all of the data I have seen to date, except for the iceberg problem, the environmental parameters for the North Sea and for the Canadian East Coast offshore are very similar and so the experience and technology developed for operating in the North Sea can be directly transferrable here.

The uncertainty over which of the analysis

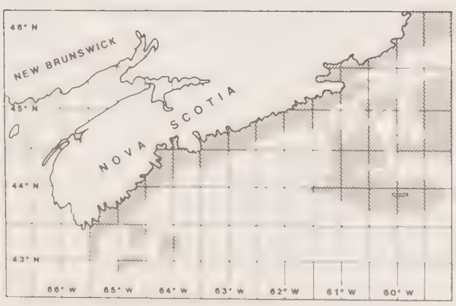


FIGURE 2 Possible area of jackup operations offshore Nova Scotia. Hatching indicates probable all-year operational feasibility against 100 year extremes subject to sea-bed conditions.
(Prepared by Noble, Denton and Associates)

methods and fatigue curves to choose, or which wave height distribution is appropriate boils down to the layman selecting a conservative approach and making sure detailed in-service inspections are carried out in a time frame indicated by the analysis methods.

What happens when we detect a fatigue crack? Do we weld it up and set the fatigue life back to zero and start again? The indication is that by grinding out a sufficient part of material on either side of the cracked area, we may indeed be able to set the fatigue life back to zero at that particular spot on the rig. The thing to be cautious about is the joint that was less critical the first time around may then be the next one to crack because its fatigue life was not set back to zero. Obviously I am simplifying the problem, but a great deal of research is going on at the moment by the Welding Institute in Abingdon, England, to find out which of the various repair techniques provides the most efficient way of obtaining useful extensions in the fatigue life of tubular joints. Their research also involves determining whether it is sufficient to repair only the cracked area of the joint or whether other areas which have accumulated fatigue damage without showing detectable cracking must be treated.

Subject then to the constraints that it is necessary to establish with a feasibility study, the limitations of the unit and its ability to work in a designated area, together with the constraint of a rigorous inspection program, what other environmental factors need to be considered? At any particular location we need to consider the ability of the anchors to hold the unit on location and thus we have to examine the sea bottom soil parameters. One needs to make sure that there are no submarine cables or buried pipelines that can be ruptured by dragging an anchor across them and it is necessary to confirm the absence of underwater obstructions or hazards which could endanger the mooring system of the unit. The calculations on moorings as outlined in the paper refer to the area from the anchor upwards. Obviously neither a designer nor the classification society, when looking at a unit, can tell you that the system will actually hold because this is dependent on the soil conditions at the specific location. We can recall the winter of 1973 when several units broke their moorings in the North Sea, and in 1982, in the North Sea, during the transient motion resulting from a double anchor line failure, a platform took with it the complete BOP and left the well open to the sea (3).

Selecting the anchors to be installed on these rigs represents, at best, a compromise, since it may be necessary to moor rigs in a variety of seabeds. It is always desirable to make sure that the bottom at the site where the unit is to be used is suitable for the anchors which are actually on the unit. In some circumstances, if the anchors wil[l] not bite in, it is necessary to switch anchors or to piggyback anchors to make sure the unit will stay on location in a reasonable storm condition.

There is no practical way of testing the anchor to its full capability. Pretensioning, which loads an anchor to somewhere around 60% of the load it expects to see in the most severe storm condition is usually carried out. This pretension is usually held for about an hour or so to prove the line. Whether the anchor will actually hold when it is needed depends on a variety of things including the dynamic forces on the mooring lines, any chafing on the line at the seabed and the general condition of the line. The analytical work is carried out assuming tha[t] all equipment is in new or like-new condition and has not been subjected to loadings in excess of its fatigue life.

Although there are sometimes problems with the analytical tools, the industry recognizes the shortcomings of the analysis methods and compensates for them with suitably conservative safety factors. Sometimes the safety factors may be too conservative. For instance, recent research on wind forces has indicated that the wind forces on semisubmersibles are generally overestimated. This is because many of the guidelines do not take the effect of shielding into account nor do they take into account the lift forces both above and below water. The presen[t] indications are that the wind forces may be less than the calculated ones, which means the safety is higher than we calculate. This also could mean that variable load weight could be increased may be by 400 to 500 tons on a typical semisubmersible withou[t] affecting its safety.

A great deal more research has to be done in the area of the effect of combined wind and wave effects on semisubmersibles. In Canada, the recently completed Boundar[y] Layer Wind Tunnel at the University o[f] Western Ontario under Dr. Alan Davenport's direction, offers a unique opportunity fo[r] research of this type.

THE ENVIRONMENT AND JACK-UP RIGS

Environmental factors are also an importan[t] consideration for jack-up drilling units. Several jack-ups are in use in offshore Nov[a] Scotia and there is potential for use in other parts of the study area of the Royal Commission.

In Table 1 typical values for wind spee[d] and wave height off the East Coast [o]

Typical Meteorological Data (50 Year Return)			
Extreme	Gulf of Mexico	North Sea	E. Coast Canada
Wave (feet)	52	60	95
Wind (knots)	131	80	88
Current (knots)	1.8	1.0	2.2

TABLE 1

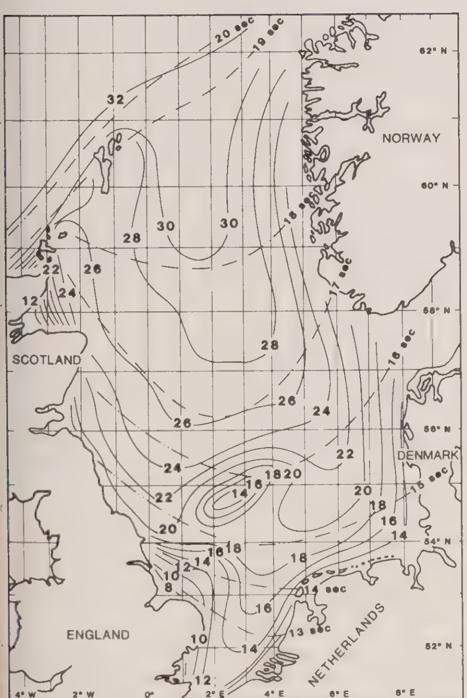


FIGURE 3 Fifty year extreme wave height (metres) and associated crest to crest period (seconds).
(Reproduced from North Sea Environmental Guide by kind permission of O.P.L.)

Canada are compared with conditions in the Gulf of Mexico and the North Sea. Since wave force is usually the largest contributor to overall forces on a unit at a particular location, it can be seen that the meteorological conditions offshore eastern Canada are probably more severe than anywhere that jack-up units have been used so far.

Quite clearly jack-up rigs built to date would not be able to withstand the force of an iceberg impact. In areas where there is a possibility of icebergs, the iceberg encounter probability should be calculated and shown to be below an acceptable risk level. The calculation should take in account weather conditions required for the unit to jack down and get out of the way of an iceberg on a collision path. Generally, for jacking up and down, a period must be available where wave heights do not exceed approximately five feet. There is at least one device, the SeaTek Slo-Roll System, which stabilizes the motion of a jack-up rig and can permit jacking into and out of the water in up to 15 foot waves. One of these devices is fitted to the *Glomar Labrador I* jack-up currently operating off Nova Scotia.

For environmental input to the jack-up design, a designer would typically select one or two water depths, one or two wave heights, and one wind speed distribution. It would be impossible for a jack-up rig designer to consider all the areas of the world and all the locations a rig is likely to drill in its lifetime. A unit may drill in Alaska one year, Canada the next, Africa the next, and so on. In each of these areas there may be specific environmental problems: high waves, strong currents, and a variety of seabeds. The number of variables would be too large to contain in an operational manual and the cost prohibitive.

Consequently, for a jack-up rig it is necessary to check that the site specific data on a location is compatible with the environmental parameters set by the designers. This can be done by obtaining data on the extremes of wind, wave, and current based on the COGLA requirement of 100-year return data from a reputable meteorological consultant. Regretfully, not all experts with the same data will draw the extrapolation lines the same way, so one often gets conflicting data for the same site. This can lead to undesirable competition for the lowest meteorological data.

In establishing the environmental extremes it is desirable to construct a set of maps showing the contours of extremes for the whole area as a benchmark for all site specific studies. These maps should, if possible, be endorsed by a government regulatory authority. Figure 3 shows the 50-year extreme waves offshore North Sea; these were derived by the author's company (5).

Although such maps are in existence for generalized wave climate offshore Canada, they are not yet publicly available. Since the design of a jack-up rig is directly dependent on wave height, it is very important to establish this benchmark so that meteorological consultants are not competing for the lowest wave at a specific site, since this infringes on the safety of the rig.

CONCLUSION

Clearly, environmental factors are of paramount importance as an input to design, and environmental parameters at the operating location must be compared to those used in the design to result in a safe operation for either semisubmersibles or jack-ups.

References

(1) Kuo C., Lee A., Welya Y., and Martin J., "Semi-Submersible Intact Stability – Static and Dynamic Assessment and Steady Tilt in Waves", O.T.C. 2976, 1977.
(2) Kallaby, T. and Price, T.B., "Evaluation of Fatigue Considerations in the Design of Framed Offshore Structures", Offshore Technology Conference, O.T.C. 2609, 1976.
(3) Havig, K.M., "New Norwegian Regulations for Semi-Submersible Units", Symposium on Semi-Submersible: The New Generations, March 17-18, 1983.
(4) Blackham, Capt. A., and Cowling, G.A., "Construction and Use of Contour Maps of Environmental Extremes", International Symposium on Wave and Wind Climate Worldwide, April 1984.
(5) The North Sea Environmental Guide, Oilfield Publication Ltd., England.

COMMENTARY ON PAPER B2

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Mobil Oil Canada Ltd.

INTRODUCTION

Mr. Bainbridge has made an excellent presentation of some of the effects the environment can have on a semisubmersible. He has also pointed out some of the inconsistencies between classification societies of different nations and the anomalies that may occur if one is not careful in examining all the variations and combinations of environmental loadings. If there is a shortcoming of the paper, it is one that is characteristic of classification society publications; that is, he does not explain the rationale used in selecting basic criteria, safety factors, and the basic loading algorithms. In addition, and of particular importance in the area of the northern Grand Banks, he includes ice loading as a section of "other loads" but does not describe how the classification societies would expect a designer to calculate these loads, and allow for them in the scantling design.

DISCUSSION

In order to elaborate on the paragraph above, I will make my comments in the order the topics appear in Mr. Bainbridge's paper.

In the analysis section, the author describes in general terms the algorithm (LOADS) that is used to determine the environmental loads on a semisubmersible due to wind, waves and currents. Unfortunately, he does not discuss the basic equations or physical relations that are used to convert the environment to loads. It is one thing to go to a classification society's "rules" and another to understand the basis from which these rules were derived. With his experience and expertise, Mr. Bainbridge could have done the designers and the Commission a great service if he would have related the basic physical relations to the predicted loads on the structure. In this manner, he could have provided insight on what effect errors in drag coefficients, inertial coefficients, wave lengths, and wave periods would have on the loadings.

In the section on "other loads", Mr. Bainbridge delineates some of the other loads that must be taken into consideration. Of particular interest are the environmental loadings due to icing and ice which are highly relevant in the Grand Banks area. It would be significant if a relationship to specific ice conditions, such as solid ice, broken ice, and load could be provided. Guidance on icing loads, their rate of accumulation, the maximum allowable accumulation, and the location of accumulation would be very useful.

The author points out that National Regulations generally give little or no guidance on acceptable basic scantlings on the assumption that the unit will be classed by a recognized classification society. This is an important point in a country just establishing its regulatory posture. He also points out that the design conditions are, in reality, envelopes of environmental criteria associated with operation limitations, combined with acceptable factors of safety. In other words, a good deal of engineering judgement is involved.

The author describes two design conditions the survival condition and the operating condition. He indicates that the survival condition is based on the 50-year storm. It would be of interest to know the rationale Lloyd's has used to arrive at the 50-year storm and not a 100-year storm, and whether the 50-year storm is equivalent to the 50-year wave, or the 50-year current. It is my understanding the other classification societies use a longer return period criteria. It also would be of interest to understand why the mooring system has to be designed to the concurrent maximums of wind, wave and current in the most unfavourable heading, rather than some joint probability of these occurrences.

The author points out the conflict between the API RP 2P recommendation of the use of a one minute wind and the DNV recommendation of the use of a one hour wind, the difference resulting in a 30% decrease in the steady line tension. Can the author provide any guidance on which to use and why?

The information presented by the author on the sensitivity studies related to stress variation with wave height and direction are enlightening. Figure 9 shows an apparent significant increase in stress in transverse members with a beam on sea. Does this mean a symmetrical semisubmersible will be more efficient than a rectangular semi because of a more even distribution of stress due to changes in wind direction?

The author points out in Figure 11 that under Lloyd's rules, the maximum bracing stress occurs in the survival conditions; however, it is not clear that the maximum stress occurs at a wave height less than the maximum wave height. If this is so, could the author explain why this would occur in the survival condition, and not in the operational or transit condition? It is of interest to note that, if one permits a different allowable stress for different drafts, one can inter-

pret Figure 11 as indicating that the maximum stresses are experienced at the operational conditions, NOT in the survival conditions.

It is enlightening to see from Figure 17 that a majority of the fatigue damage is accounted for by relative low wave heights (3 to 6m) between the 6 to 10 second zero crossing periods, but could the author explain the meaning of the number in the squares of the scatter diagram?

Another anomaly pointed out by the author is the difference in the American Welding Society and U.K. Department of Energy welding standards and the effect it has on the interpretation of the amount of damage that could occur. Could the author comment on such differences, particularly in light of the Commission's charge to make recommendations as to guidelines and criteria?

In summary and conclusion, the author did a fine job in explaining what environmental loads should be considered in analyzing a semi, but did not explain how the environment factors could be translated to design criteria. He provided considerable insight into the sensitivity of environmental loads to wave height, period and direction, and last but not least, he pointed out the various inconsistencies among the various world standards and guidelines.

Summary of General Discussion Following Papers B1 and B2

Session Chairman R.A. Hemstock opened the discussion period with a written question from G.L. Hargreaves (Consultant, U.K.) regarding the application by engineers of the U.K. Dept. of Energy's published S/N (nominal stress) curves in taking into account the problem of "fatigue life" in the design process. Mr. C.A. Bainbridge (Lloyd's Register of Shipping) responded by saying that there are problems with the interpretation of the curves as they exist, particularly when applied to offshore structures where loads are from waves rather than from repeated "known loads". Mr. Ray Street (Hollobone, Hibbert) inquired whether current U.K. research on fatigue and fatigue curves is being effective, in view of the financial support provided. Mr. Bainbridge replied that new curves are being introduced, but only for tubular joints.

Dr. R.B. Wardlaw (NRC) referred to the importance of wind loads in structural design, since they affect mooring loads and the natural frequencies of rig motions. He also emphasized the importance of a correct interpretation of the 100-year return wind (or wave): that it means a one in one hundred probability of such a wind (or wave) occurring in any given year.

Dr. B.P.M. Sharples (Noble, Denton) agreed that consideration of wind loads is indeed important and that the variability of the wind creates loads which can produce a fatigue effect on a structure. There is ongoing research by the Society of Naval Architects and Marine Engineers (SNAME) in this direction, particularly as it affects semisubmersibles. He pointed out, however, that care should be taken to ensure that new wind load data do not offset current practices in other areas of structural design.

Dr. G.P. Vance (Mobil Oil Canada) asked Mr. Bainbridge whether a symmetrically-shaped semisubmersible with a box girder, as opposed to two pontoons, would be more structurally efficient. Mr. Bainbridge replied that it has been shown that such a non-square configuration displays better motion characteristics and less resistance during towing.

Mr. F. Dello Stritto (Mobil Oil Canada) asserted that the skeptical attitude towards environmental data (particularly wave heights) on the part of oceanographers, ocean engineers, structural engineers, and designers is healthy, as it results in an intrinsic review system throughout the design process. It also results in these specialists becoming more adept at discussing that data in a critical way, and being conservative in their estimates of wave loads, current loads, and icing loads. The people using the data are aware of the inadequacies of the data acquisition and analysis methods and are therefore cautious in use of them in the design process. Dr. Sharples agreed with Mr. Dello Stritto that wave height data do present problems, particularly when approval of a unit for a specific site is sought from regulatory authorities who must also interpret the data.

In relation to the inadequacies of weather forecasting methods, Mr. Dello Stritto noted that the present inability to forecast mesoscale storms can have disastrous effects on vessels and structures offshore. He pointed out that the use by Dr. Ford of the 60 to 140 knot range in estimate of the 100-year wind at Hibernia gives an inaccurate impression because available methods can provide a much smaller range of predictions. Mr. V. Swail (Atmospheric Environment Service, Environment Canada) said that the climate study of which he was an author cited the 60 to 140 knot range on the basis that available published literature provides values throughout that range. He agreed that the range would be less if current knowledge and methods were used, but would probably not be reduced by more than one-half.

Mr. Dello Stritto also criticized the lack of any Canadian regulation requiring operators who intend to use a jack-up platform to submit borehole data for the site selected. He emphasized that most companies do, in fact, obtain borehole samples of a selected site, despite the lack of such a regulation. Although stating that such a regulation was in order, he cautioned that such a requirement would also result in a decrease of incentive on the part of the operator. Mr. L. Brandon (COGLA) pointed out that a guideline, not a regulation, does exist which requires that the geotechnical engineer employed by the operator submit a report to COGLA on the seabed in question and that the engineer also be present during the jacking up operation. Mr. Brandon also pointed out that this form of regulatory procedure places the onus of responsibility on the industry, a process which was encouraged by Mr. G.R. Harrison in his introductory address.

Mr. W.H. Michel (Friede & Goldman) added that designers have additional problems of definition of wave height data: is wave height measured from crest to trough of the highest wave; or, is it the double amplitude of a crest? Mr. L. Draper (Institute of Oceanographic Sciences, U.K.) disagreed with Mr. Michel's second definition, saying that oceanographers deal only with crest-to-trough wave heights. Mr. Michel, however, insisted that designers are faced with this dilemma and he emphasized that it is the amplitude of waves that causes the force and motion characteristics which are necessary considerations in design.

Mr. Swail enlarged on the consideration of wind loads, and expressed concern that these loads were being downplayed. He referred to current research in the wind tunnel at the University of Western Ontario, where tests are showing that wind loads are, under certain conditions, potentially as high as wave loads. Mr. Sharples agreed that the effects of combined wind and wave loads on semisubmersibles are still unknown and certainly warrant investigation. Dr. Wardlaw pointed out that NRC is also aware of the effects of wind loads and is therefore active in pursuing the idea of simultaneous modelling of wind, waves, and current. The National Research Council would welcome comments or suggestions on this research topic.

Another area of concern identified by Mr Swail was the effect of ice accumulation particularly when combined with wind and/or wave loads. These combined loads could have significant impact on safety both for the individuals on deck, as well as for the entire rig.

Mr. J. Benoit (Mobil Oil Canada) addressed Dr. Ford's concern with bergy bits and growlers, and the difficulty of using radar to track them. He said that industry along with the International Ice Patrol, has found that these smaller pieces of ice, which tend to deteriorate as rapidly as within one day due to water temperature and wave action, are not randomly distributed but are nearly always clustered in the general area of a larger berg (from which they have calved). This means that bergy bits can be more readily tracked. Studies conducted under the Environmental Studies Revolving Fund are aimed at improving detection techniques for both the large bergs and the smaller pieces of ice. Dr. Ford pointed out that radar detection ranges for icebergs are based on theoretical calculations which need field verification provided through the current research.

Mr. W. Michel
Vice-President
Friede & Goldman Limited

Mr. Michel is a Naval Architect with extensive experience in design engineering and construction. He has been with Friede & Goldman Ltd. for 23 years with responsibilities for research and development of all types of marine vessels. He is also engaged in detailed structural and hydrodynamic studies for new types of vessels and the development of new features. His specialties include ship resistance and propulsion, sea behaviour, and advanced hydrodynamic and structural analysis. Mr. Michel is a member of SNAME and has served on a number of its committees; he is presently a member of the ABS Rules Committee on Mobile Offshore Units.

PAPER C1

Design Principles and Process for Safe Operations Offshore

INTRODUCTION

In order to address the subject of design principles for safe operations offshore, it is necessary to refer back to practices that have existed for the last two decades, some of which have been established as sound in judgement and execution and some of which remain suspect, though expeditious and presumably attractive. We must begin with the observation that the first rules and regulations for mobile offshore drilling units were established by the offshore industry itself – a set of principles and formulations proffered by the collective action of designers, owners, and operators of offshore drilling units to the American Bureau of Shipping, for administration and certification purposes. That agency's first set of rules for MODU's was established in 1968 and has formed the basis for all worldwide regulations that have since been promulgated.

In following years, there have been a number of rule modifications and clarifications resulting from further experience and deeper consideration of basic requirements. However, not all major considerations of structure and stability are sufficiently addressed, and research has been sporadic. Only since the several major catastrophes which have most recently occurred, has there been any concerted effort to re-examine the principles and processes for proper design of mobile offshore units.

This paper will present a number of design features and practices for semi-submersible and jack-up units that we have developed over several decades of experience in this field, toward the end of establishing a sound structure capable of sustaining the environment that confronts it. As such, it may be considered as a follow-up on paper No. 14 of the Design-Inspection-Redundancy Symposium, given at Williamsburg, Virginia in November, 1983, which stressed the need for further research on structures and stability, control of construction and inspection, and re-examination of certain vital design formulations.

For purposes of immediate referral to the intent of the present paper, we will restate the summary and conclusions from that previous paper (Reference 1). A broad view of major problem areas in considerations of design inspection, and redundancy has been presented, with emphasis on those aspects to which early attention should be directed. Proper treatment ranges from simple "cleaning house" exercises, which must first be attended to, to in-depth analysis and research for those matters not yet fully within grasp. The following should be considered:

1. Resolution should be made of such issues as the need for more unified and proper formulations for deep tank scantlings for semi-submersibles, and the need for more rigorous inspection during construction.
2. Hull girder requirements need to be reanalyzed in depth, particularly in regard to structural stability for the lightly-scantlinged upper hulls, and in the presence of multiple cut-outs.
3. Research is imperative on high cycle fatigue, particularly in regard to the development of proper S-N relationships for the particular types of fabrication details utilized in floating platforms.
4. Continued development of fracture mechanics methods should be maintained, toward prediction of low cycle fatigue. It is recommended that statistical studies be made of the size and character of flaws likely to be undetected during construction inspection, as discovered in later surveys.
5. Further testing and analysis is indicated for resolving wind effects on semi-submersibles, and with the ultimate necessity for conducting research on the combined wind and wave effects to establish proper criteria.
6. Development of a more precise methodology is necessary for wave loadings and their structural consequences, for jack-up units under severe environment in deeper waters. Model tests of jack-ups in elevated positions to establish parameters of damping, amplification, and ultimate spectral analysis approach are considered essential.
7. A comprehensive study using risk analysis techniques is needed to establish justification for redundancy requirements in regard to loss of major components, such as a complete jack-up leg, a semi-sub caisson or hull, etc.

SEMI-SUBMERSIBLES

General Structural Considerations

A typical twin hull, semi configuration is shown in Figure 1, which depicts the "Pacesetter" class developed by our firm, of which more than twenty units have been built since the first one completed for the Western Company in 1972. It shows three caissons on each hull, with a full set of horizontal and diagonal bracings, supporting a grid beam type of platform deck. Some designs of other firms have employed four caissons per side, and some (with a full top-

side hull structure) only two per side.

Our basic philosophy has been to triangulate the structure to minimize rotational moments at critical structural joints, such as develop with portal frames and Vierendeel trusses, particularly under lateral loads. In some cases, where we have employed full box hulls as the top side structure, the diagonal braces in the fore and aft direction have been eliminated, but only after detailed examination of probable stress levels under extreme environmental loads. In this latter regard, it may be noted that for the pipelayer *Castoro 6*, which has a complete upper hull, and lower hulls with five caissons per side (almost two Pacesetters, end to end), it was considered necessary to brace every longitudinal bay to minimize bending stresses that would otherwise develop under the classical longitudinal ship bending loading. In any event, in consideration of the high lateral load that can occur on a semisubmersible under severe environment, we believe that properly oriented diagonal bracing is essential to insure against inordinate bending stresses being developed in critical areas. We do not have the temerity to eliminate them entirely.

In determining the wave loadings to be used in the space frame structural analysis we rely to a large degree on model tests, not only to establish motions, but for direct read-out of forces and moments on the structural elements under maximum sea conditions at survival draft, as well as specified sea conditions for transit and drilling modes. For any significant change in dimensions, although the general configuration may be the same, we will conduct new tests to confirm any analytical projection that may have been made for preliminary evaluation. With this information as input, along with service and operational loadings, about twenty different combined load conditions are analyzed, covering the gamut of all anticipated situations, to establish the validity of the overall structure.

Lower Hulls and Caissons

Typically, the shell and bulkhead plating and framing of the lower hulls and caissons of a semi-submersible are sized on the basis of deep tank formations. In general, the resulting scantlings are sufficient to enable these members to act effectively as space frame elements, at nominal stress levels within allowables (except in the highly loaded areas of hull/caisson bracing intersections, where reinforcement is usually required).

In our practice, we establish these scantlings on the basis of the full head to the top of the overflow (plus friction head), rather than the normally accepted two-thirds height as applied in surface ships, in consideration of the fact that semi deep tanks are pressure-filled at a high flow rate and resulting overflow in service is not uncommon. Further, we view the margin normally applied to the scantlings to be more an experience factor than a corrosion allowance, and we do not reduce scantlings even though all surfaces are corrosion protected. Even more, the thickness of the external shell plating is further increased to minimize the possibility of rupture under damage, which would be difficult to repair for such areas that are inaccessible.

In further consideration of the importance of maintaining the integrity of all compartments in the hulls and caissons, from both a structural and stability standpoint, our specifications require that all tanks be tested to the full overflow height, to insure sound construction as well as adequate design.

Horizontal Bracings

These are the most critical structural members of the semi-submersibles, providing the means of holding the lower hulls and caissons together. Essentially, they are tension members under the direct loading of top side weight and service loads, accentuated by mooring and wave spreading forces on the caissons and lower hulls. While these latter loadings are cyclic and influence fatigue life, the ultimate failure mode is nevertheless that of tension, and special attention must be given to the structural arrangement of these members, both in design and construction, to minimize the possibility of catastrophic parting of the bracing. To this end, the structural design of the horizontal bracings, as employed by this firm, may be delineated as follows:

1. The bracings are completely watertight, with access openings from within the caissons to allow for dry inspection of the inner structure, without the need for raising the unit.
2. Monitoring devices are installed to allow remote checking of the internal volume of the bracing, to detect possible water leakage from structural cracks.
3. A number of heavy T-beam longitudinal stringers are installed internally around the periphery of the cylindrical shell of the bracing, extending continuously between end attachments, Figure 2. These, in association with the ring frames needed to prevent shell collapse under water pressure forces, form a highly resistful structural grid to minimize local damage due to wave impact and/or collision (particularly during the transit mode). Of further and critical importance is the redundancy provided by these stringers, toward restraining the propogation of shell cracks that may develop under a fatigue or damage situation. In this latter regard, we further specify that the butt weld attachments of the stringers be offset sufficiently from the butt welds of the tubular shell.
4. Finally, in way of critical joints, the bracing shell plate is increased in thickness and the longitudinal stiffeners are faired into heavy internal diaphragm plates that continue directly through the joint as part of the adjacent caisson/hull structure, Figure 3. These joint scantlings are so determined that the nominal stress level is approximately one-half that allowable under the maximum conditions of loading. Detailed finite element analysis of the resulting joint structure indicates that the maximum local stress intensity would not exceed the full allowable and, thereby, for considerations of fatigue, the only stress concentration factors that need to be considered would be those of welding and fabrication which are reasonably well assessed from established codes.

Vertical Diagonal Bracings

Similar consideration and treatment are given to the bracings that support the upper structure, with the one exception that longitudinal stiffeners along the bracings are omitted. In this case, the bracings are essentially compression members and the need for redundant internal elements is not mandated. Further, the intensity of wave impact loadings is significantly less, and while the possibility of local damage due to support vessels while in operating condition is fairly likely (and occurs frequently enough), the risk of calamity is minimal insofar as those peripheral braces are not in a high stress condition under these operations, and any damage of consequence is readily observed and repaired.

In any event, it may be noted that the Pacesetter bracing system has the built-in redundancy that is now becoming a requirement of several regulatory bodies, wherein the loss of any one bracing will not cause collapse of the overall structure. What is not addressed by most regulatory and classification bodies is the detailed design requirements for the individual bracings themselves, such as outlined above, in regard to inspectability, redundancy within tension members, etc. Attention should be given to these considerations to minimize the possibility that a bracing loss will occur.

Upper Platform Structure

From a purely structural standpoint, our favorite type of upper structure has been the open grid beam configuration, on which platform decks, deck houses, sub-structures, pipe racks, etc., are constructed as

FIGURE 1

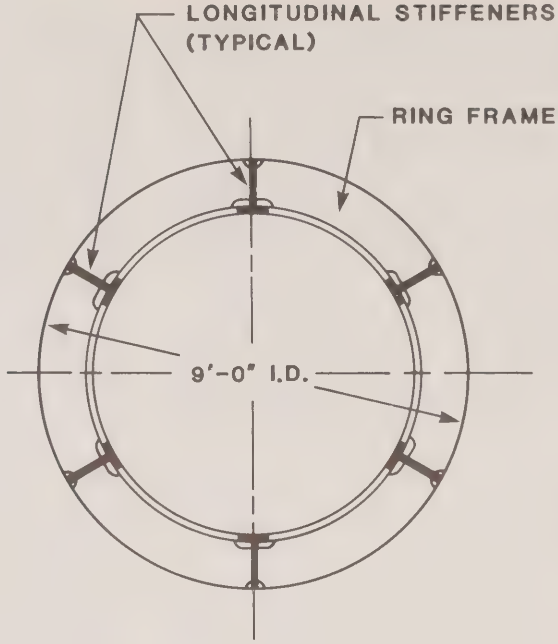

FIGURE 2

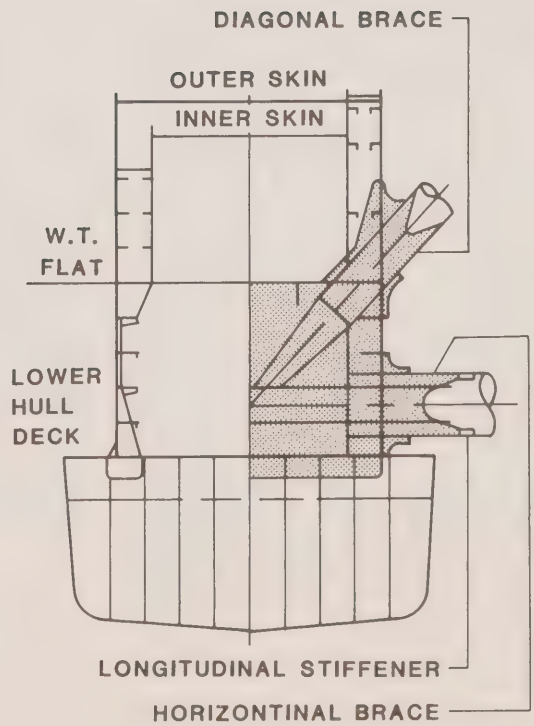

FIGURE 3

the need and arrangement require. We have confidence in the design methodology dictated from civil codes and practices of long years standing, for such similar structures as highway bridge and building girders, wherein loading patterns are similar and structural details are mandated to account for high shear and moment transfers under significant bearing loads and joint supports. We have used this system on a majority of our units.

The present vogue is to utilize a full box upper hull, with most of the power equipment, drilling and ship service installations, and quarters neatly compartmented within. Its attractiveness lies in a more uniformly available upper deck space for drilling storage and operations, and a generally more sheltered area for systems and for habitability against wind and cold (in the Northern climes, of course; not so advantageous in the Gulf of Mexico or similar hot environs).

Its main purpose, nevertheless, is to more easily meet the flotation requirements for the latest damage stability regulations of several European authorities.

Structurally, however, the full box upper hull is suspect as to its adequacy to meet the service and environmental loads to which it is subject. It is stiff beyond a doubt, which tempts many designers to eliminate bracings, but which can cause high local stressing (and straining) at important connection areas. There is no basic experience factor for very thin skinned boxes subject to high local bearing and support loadings, of the proportions indicated for the typical semi-submersible. Finite element analyses are the only expedient and these can lead to complacent conclusions, wherein one may not have modeled a major deck hatch opening or a large access opening in a vital bulkhead, or whatever similar omission that may be critical.

Nevertheless, the box upper hull is here to stay. For our units so built, we establish a grid pattern of major bulkheads and associated deck and bottom "flanges" of high strength plating to simulate the open grid structure that we favor. We attempt to establish (by specification and inspection) that these areas remain sacrosanct from unauthorized penetrations or those without reinforcement. We view this procedure as a measure of redundancy against any possible fracture or failure of the "stressed-skin" of the box hull.

Stability Considerations

Since the development of the first set of requirements for mobile unit stability, issued by the American Bureau of Shipping in 1968, our organization has been trying to interest any and all concerned with offshore activities in developing requirements that more rationally and accurately take into account the effects of all of the environment – wind, sea and current – rather than continue with belaboring a wind only criterion that uses arbitrary and uncorroborated factors. Aside from the one research effort conducted in the early 70's (Reference 2), and which produced definite results sufficient to encourage futher investigation, there has been little support shown for additional research throughout the industry. It would appear to us that from the standpoint of safety at sea, governmental regulatory bodies and classification agencies, if no one else, need to have established a proper set of criteria. We will keep trying.

On the matter of new regulations and proposals concerning damage stability, we endorse the requirement that under one (realistically two) compartment damage, the unit shall not heel beyond 15 degrees and all major survival systems shall remain operative and effective, including ballast. This is a proper restriction and parallels that of long standing and experience for passenger ships, wherein 15 degrees is considered a limiting angle for emergency operations and personnel safety.

However, we fail to see the validity or to understand the rationale for the proposal that under a calamitous loss of buoyancy (typically the loss of a caisson) the unit shall survive a heel of 35 degrees (magic number) and that measures are provided aboard to restore it to some more amenable position. From units that have already met such requirements, or presumably so, we have seen that some of the necessary provisions occasion greater casualty risk under more probable circumstances; for example, the restriction of normal escape routes (the only acceptable one being toward the well center – the well center?).

We have had to address these later requirements in several instances where rig owners have specified their need to operate under such regulations. We have done so with misgivings, but to the best of our ability to accomplish the purpose without undue sacrifice of the features that make the unit effective, efficient and safe under more probable circumstances. We continue to maintain our objection.

JACK-UPS (SELF-ELEVATING UNITS)

General Considerations

The operating modes under which different types of structural analysis must be performed for jack-up units may be presented in chronological order:

1. The unit is in transit from some previous station to the desired site, typically afloat on its own hull with its legs fully raised.

2. On location, it lowers its legs until positive touchdown to the sea floor and then jacks up the hull to a point where pre-loading can be accomplished to prove out the bearing capability of the soil, and then finally it jacks up to a designated height above sea level where the hull is secured for drilling operations.

3. In its final elevated position for drilling operations, the unit must sustain its structural integrity under the various combinations of operating load and environment (sea, current, and wind) as specified for the particular location.

It is of definite interest to note that the severest casualties, experienced over the 25 years or so of jack-up operation, occurred in the same descending order. Most casualties that have resulted in loss of life, as well as the unit itself, have occurred while in transit; to a less severe degree (although more numerous regarding leg damage) when lowering and raising the unit; and virtually nothing when in the jacked-up position under the prescribed environment. Despite this, design emphasis has been in the opposite order for the very significant reason that the unit is to be built for the purpose intended, drilling while in the elevated position, and all other situations are necessarily given secondary consideration.

The basic principles on which the structural design should be based are covered in excellent fashion in the classification note on self-elevating units issued by Det norske Veritas (Reference 3). It is intended here to present some of the detail structural considerations to satisfy such principles under maximum design conditions for the various modes of operation that the jack-up is subjected to. Such information is based on the particular type of unit that we have developed; the three-legged jack-up, wherein each leg is truss type with three chords and independent footings, and where elevating means is by rack and pinion. Figure 4 shows the typical configuration of our design designated as the L-780 series, of which more than twenty-five units have been built since 1980.

Unit in Elevated Position

With the unit in fully elevated position, the main structural consideration is that to withstand the horizontal forces of wind, wave and current while supporting the topside weight of hull, equipment, and supplies. The overall configuration may be visualized as a portal frame supported at the ocean floor and requiring some rigidification at the leg/hull connections to maintain structural

stability, Figure 5.

Regarding the development of the horizontal forces for a specified set of environmental factors, it may first be noted that computational methods for determining wind forces have been reasonably confirmed by wind tunnel tests on components of hull and legs, as well as the entire assembly, to where there is little room for controversy or misguidance. However, such is not the case for wave and current forces, whose combined effects become the over-riding force consideration for more severe sea conditions and in deeper water.

The generally required theory for wave, plus current forces, has been that of shallow water, finite height, regular two-dimensional waves of Stokes' 5th or Stream Function type, to establish wave particle velocities to which the current velocity (anybody's guess) is added, and the forces on the legs determined as a function of the combined velocity and "suitably established" drag coefficients for the leg components. Insofar as the early jack-up developments were in fairly shallow water with significant wave steepness and storm tide surges, this was the only reasonable approach. The practice has been carried forward to where it is still applied for water depths of 300 feet and more, but where its use is highly questionable as an accurate representation.

Whether because of its conservatism, or whether all of the design environmental factors were never collectively experienced, the fact that there has been minimal evidence of casualty in this attitude has lead to some relaxation of requirements by several agencies. For example, when using this theory, one agency will allow a lower leg drag coefficient and another will allow calculated leg stresses to approach the yield strength of the material. We satisfy ourselves with the view that our drag coefficients and our calculated stresses are of the right order and take the conservatism as a margin against untoward events or undetected construction errors.

However, when considering water depths over 300 feet, the need for a more realistic appraisal of wave plus current effects becomes necessary. With longer leg lengths, the natural oscillation period of the unit approaches the range of harmony with the periods of the sea waves, and the sea itself is more characteristic of irregular deep water behavior. Such considerations need to be evaluated on their own merits and not on past acceptance practices.

This is somewhat virgin territory and the need for research and well-modeled tank testing of units jacked up in water depths exceeding 300 feet, and in the presence of realistic seas, is essential toward a proper determination of the loadings imposed on the unit.

Returning to the structure itself, it is seen that the most critical and highly loaded area is that of the leg/hull connection, wherein moments of high magnitude must be absorbed over a relatively short distance. Thus, for most types of units, with the vertical load being supported by the jacking pinions, the joint moments are taken in high horizontal reactions at leg guides in the vicinity of the bottom and the main deck of the hull. These reactions produce high axial loads in the leg bracing within the support area, along with possible leg chord distortions and leg joint rotations, Figure 6.

For the independent leg type of jack-up, in different depths of water and/or different leg penetrations in different soils, practically all bracings may be subject to these high joint loadings, at one time or another, and thereby must all be sized to suit such maximum loading.

To minimize this excess use of steel, with its resulting greater leg weight, our firm developed the "Rack Chock" system of leg/hull attachment, wherein almost the entire moment reaction loading is taken vertically through the leg chords, supported at the hull bulkheads of the leg wells, with a minimum horizontal reaction, except for the shear loading of the wind force alone. Further, there is no "joint rotation" due to gear and pinion clearances when supported by the jacking system, and thus the sidesway under environmental load is minimized, as is the resulting secondary bending of the legs.

A further feature of our leg design may be noted. As shown in Figure 6, we utilize the overlapped bracing joint, both at the "K" and at the chord intersection. This is more costly construction and requires greater care in fitting up and welding, when compared to the typical open joint with or without bracket attachments, but its high strength and minimum stress concentrations make it highly desirable.

A more detailed description of our considerations of leg design and hull support has been given in the paper presented before the Memorial University of Newfoundland's seminar on Safety Management for Offshore Operations on the Canadian East Coast, in Calgary, during June, 1983 (Reference 4).

Considerations of structural requirements for the hull involve the same concern as indicated above for the upper box hull of a semi-submersible. Being the top girder of a portal frame, with high end loadings and moments, the hull scantlings cannot simply be determined in the classical ship bending manner, but full account of all specific loadings must be made, utilizing a detailed finite element approach. Particular attention must be given to the highly loaded leg support areas, in full consideration of stress concentrations and fatigue assessment (in transit mode, as well as in elevated mode).

In addition, the strength of the hull girder in transmitting loadings between legs must be viewed carefully to insure that its continuity is not sacrificed to the need (or convenience) for hatches, vents, and archways that seem to proliferate during construction and also while in service. Thus, we may see from the simplified plan, Figure 7, that the main load path tends to be along the longitudinal bulkheads that support the cantilever drilling load, but which area is prone to those numerous deck and bulkhead cutouts. We therefore run finite element analyses for two different structural situations; first, full intact structure, including major designated openings to determine the probable (or at least initial) load path and stress; and second, with the main longitudinal bulkheads made discontinuous (eliminating one bay each) so that the main load path is around the periphery of the unit, which areas are wing tanks not subject to large openings and thus considered intact.

Touchdown and Preload Conditions

Most of the accidental damage to a jack-up unit occurs during the operation of getting on location (and also getting off), from the point of leg touchdown to the jacked-up position to conduct pre-loading (and also when attempting to raise embedded legs, while the hull is afloat).

Touchdown is a fairly uncontrollable situation in any sizable sea. The motions of the unit afloat on the hull can cause leg and leg support damage due to a scraping-upon-ground contact (roll and pitch) and/or high impact (heave, with roll or pitch). Measures to alleviate such problems have been proposed, such as the "Slo-Rol" installations, for minimizing roll and pitch, and the resilient shock absorbers that we have developed to reduce heave impact. However, there has been little enthusiasm shown amongst the operators for incorporating such features, for whatever economic or operational reasons, and the tendency remains to look for the weather window under which such operations can safely be made with units as now configured. Typically, it remains a factor of experience and luck, as to whether damage will or will not occur. General instructions for conducting such operations includes the recommendation that seas should not be over about six feet high (no guarantees).

Pre-loading is conducted with the hull a minimum distance above wave disturbance, and with all ballast tanks filled, to pressure the soil to a load-carrying capacity equivalent to the maximum that can be anticipated

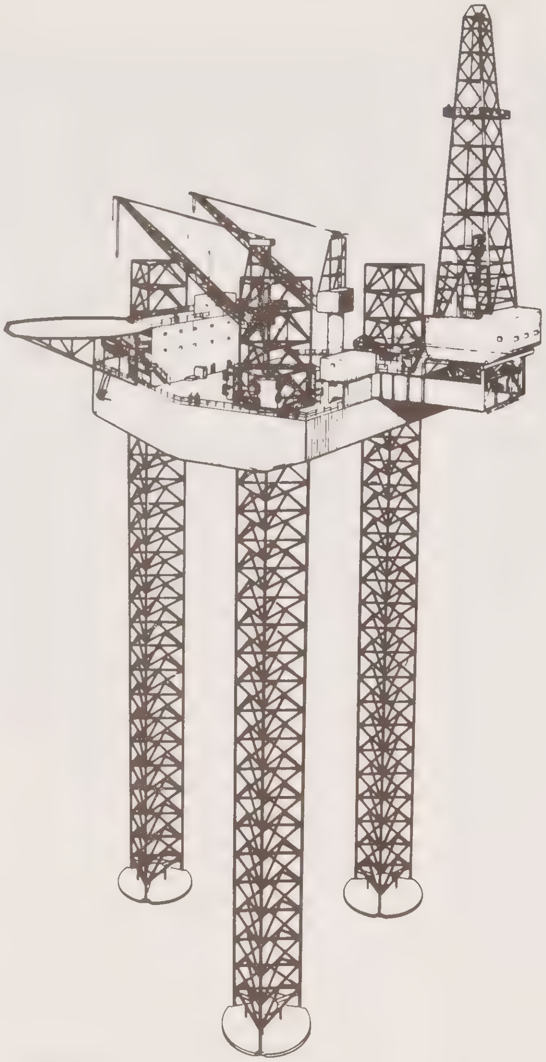

FIGURE 4

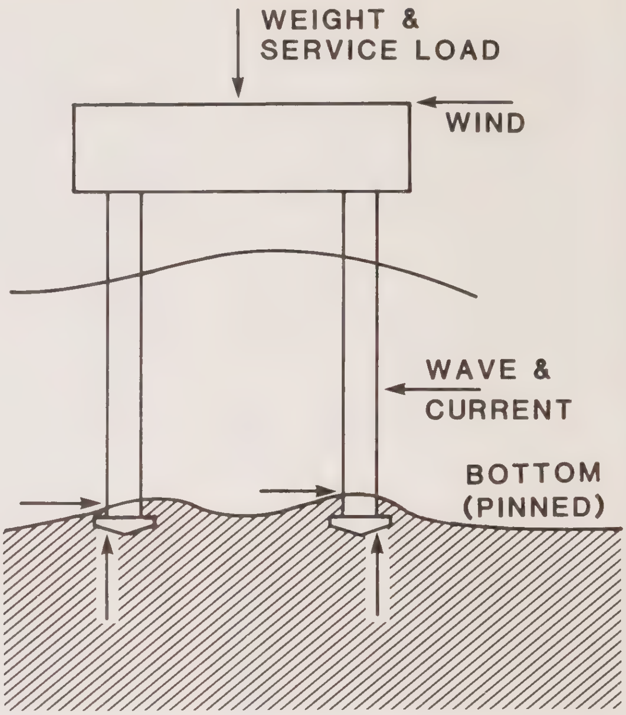

FIGURE 5

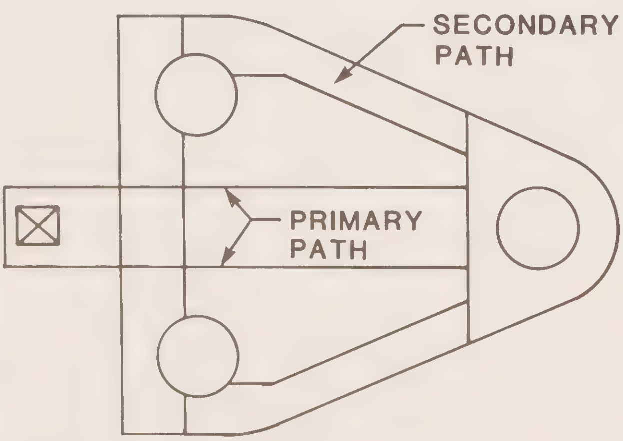

FIGURE 7

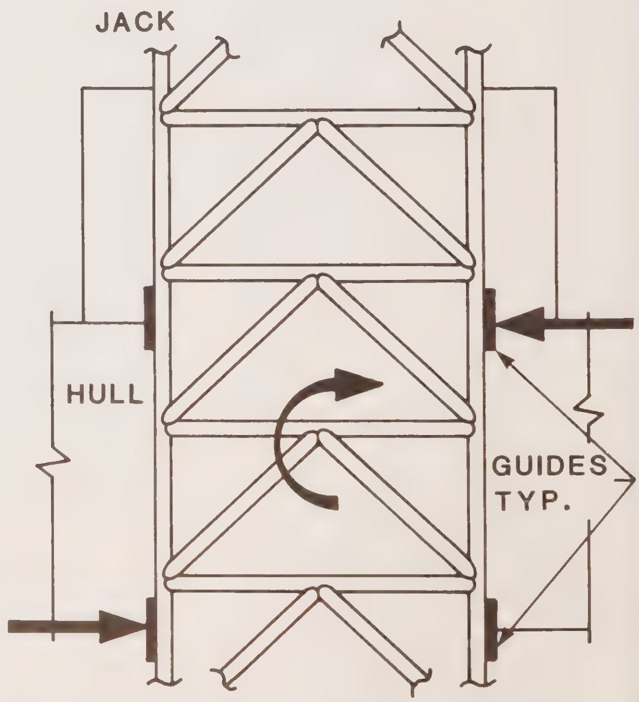

FIGURE 6

under the prescribed environmental loadings. Frequently, it is found that the soil is insufficient, and bearing is lost to where the unit lists and leg damage occurs. A method to evaluate the potential for leg damage under different assumptions of punch-through penetration, water depth, etc., has been developed (Reference 5).

Getting off location presents another hazard, whereby the hull is lowered to the afloat position and leg retraction is attempted. Under conditions where the legs are deeply imbedded, such operations may consume time, and if the wave and current forces cause considerable sway of the hull, leg damage can result.

All of these damage situations remain prevalent, to where experienced judgment may be overridden by the element of chance. Fortunately, the damage that may occur is to structural elements (principally in the legs) that are reasonably capable of being repaired, and injury or loss of life under these circumstances is a not probable consequence.

It may be noted that, for the several incidents of leg damage, the overlapped joint employed for leg bracings in our design has not failed or even cracked, despite brace buckling or fracture, which helps to affirm our belief in its superiority.

Transit

The most significant casualties, wherein both loss of life and loss of unit resulted, have occurred when in the transit condition, afloat on the hulls with legs in the elevated (or partly elevated) condition. Some of the earliest experiences may have been due to an absence of basic stability, a cracking of hull structure at the leg support area (and where flooding of adjacent spaces was uncontrolled) or unsatisfactory securing of legs leading to leg failure. Many of those situations have since been addressed by regulation and voyage survey requirements, but the situation remains precarious in regard to high leg bending and leg support loadings when in seas that may cause untoward roll/pitch motions.

Model tests conducted on our L-780 units afloat, with legs fully raised and in a range of severe irregular seas, indicate that the maximum forces and moments recorded at the leg/hull attachment closely approximate the ABS criteria of 15 degrees, 10-second roll/pitch acceleration (correspondingly less than the 20 degrees, 10-second criteria of Noble, Denton). Further analysis is required to establish whether limitations on leg length and/or voyage routes would be necessary due to considerations of low cycle, high stress fatigue, which can cause leg failure or hull cracking. Several of the principal regulatory agencies are starting to address this situation, but no definitive methodology has yet been established.

It may be noted that most long voyages today are made by "dry tow", wherein the jack-up unit is carried aboard a special ship or ship-shaped barge, to minimize time at sea. Similar roll/pitch considerations exist, depending on the ship characteristics, as well as provision of adequate dunnage and chocks to minimize hull damage under extreme sea conditions. It is beyond the rig designer's control to regulate these operations, and beyond the scope of this paper to go into details concerning this mode. In any event, sooner or later, the unit must float alone and be subject to the exigencies described above (and as follows).

Seakeeping and Stability, Afloat

While the criteria for leg strength are fairly well defined for transit conditions, afloat on the hull in severe environment, there is apparently little recognition or provision amongst the numerous regulatory agencies that the jack-up unit afloat is a poor seakeeping vessel and prone to damage conditions that may cause casualty to a greater prevalence than leg failure.

With its high vertical extent of weighty legs (whether raised or lowered) the unit has a large mass moment of inertia to where it responds sluggishly to the oncoming waves, resulting in green seas of sizable magnitude mounting over the deck. This has been experienced frequently with units in service, and is dramatically evident in model tests under severe environment. It is questionable whether the standard requirements for plating and stiffeners of barge deck house fronts are adequate and properly disposed to withstand the high impact pressures that are likely to develop.

In addition, more careful attention must be given to the strength, height, and locations of vents and overflows from spaces below deck, not only to withstand the forces imposed but to insure against down-flooding. In this regard, the normally considered stability requirements (whether intact or damaged) which presume a wind overturning factor inclining the unit in still water does not cover the situation of green seas running across the deck.

OFFSHORE DESIGN AS INFLUENCED BY RISK/SAFETY CONSIDERATIONS

It should come as no surprise that we do not use formal risk analysis in the development of our offshore designs nor to establish justification for their acceptance. We do not attempt to assign probability factors for environment, operations, or accidents or to develop confidence levels for material and welding strength and behavior, or, finally, to reflect some industrial index for acceptable loss of life and/or property. This is not our province, our responsibility, or our right.

It is the regulatory bodies that must establish these criteria, codes, and judgements on which we must produce our designs and verify their validity. Whether it be governmental agencies, classification bureaus or insurance underwriters, and however they establish their requirements, it is then the necessary obligation of the designer to satisfy them in a deterministic manner.

We do, of course, address and always have addressed the question of risk and safety in our designs. However, ours has been a qualitative assessment based on our marine experience accumulated over the years and our knowledge of offshore drilling operations. Our resultant practices in this regard, along with those of other responsible designers and rig owners and operators, are represented to a large extent in the rules and regulations that exist today throughout the world, and we continue to provide vital input toward future considerations, as members of committees and advisory boards, to the various regulatory bodies.

It may be noted in this regard that not all of the design practices we endorse have been accepted as necessary requirements by the regulatory bodies, nor conversely that those requirements we feel need revision are being acted upon, as may be construed from our presentation in the earlier portions of this paper.

Our approach to the matter of risk and safety is rather simplistic. We ask ourselves the question: "What could happen if. . .?" where "if" is the important word. If an unintended event were plausible, and if it could result in a precarious situation, we then look to answer the further question: "What can be done to prevent a major casualty?" A few examples may illustrate:

1. "If a supply vessel or other object were to strike and damage a caisson of a semi-submersible" this is plausible and happens frequently enough, and could cause unrestrained flooding and loss of stability. What is done is to require compartmentation to limit the flooding and maintain stability under some acceptable heel angle, from which measures can readily be adopted to restore the unit to its original state. It may be noted that this was one of the early safety considerations incorporated into the 1968 ABS Rules, and represented the first damage stability requirement for any vessel other than passenger ships.
2. "If a caisson of a semi-submersible completely lost all of its buoyancy" we stop with

the "if"; there is no plausibility in considering that any vessel (or iceberg?) could neatly sever a caisson, leaving everything else buoyant and intact, nor is there any other eventuality that we can conjure in this regard. There have been losses of caissons in several disasters, but these have been due to structural failures of supporting members, which has been addressed under other "if's".

3. "If a supply vessel or other object were to strike and damage the leg of a jack-up" this is plausible and has occurred, but not so frequently since boat operators have learned to avoid such confrontation at all costs (to themselves). In any event, it is plausible enough to require consideration for strength in the individual chord and bracing elements to sustain leg integrity under an incident of this type.

4. "If a large vessel (or iceberg?) were to strike and collapse a leg of a jack-up unit" this is plausible, if extremely unlikely (and has never occurred), but which would collapse the entire unit. There is no solution for any of the three (or four) independent leg units existing today.

Simplistic as this approach may be, there is little more that we can apply at present. Only when we have enough statistics on enough casualties of the same type on similar units in similar situations, can we begin to establish a reliable risk analysis methodology. With the help of divine Providence, may we increase our knowledge and wisdom, to produce offshore units of greater safety and reliability, to where such accumulation of casualty statistics may never be attained.

References

(1) W. H. Michel.
"Synthesis – Floating Offshore Platforms – Problems and Prescriptions, From Design to Inspection" Design – Inspection – Redundancy Symposium. Ship Structure Committee, November 1983.

(2) Numata, Michel, and McClure.
"Assessment of Stability Requirements for Semi-Submersible Units" SNAME Transactions, 1976.

(3) "Strength Analysis of Main Structures of Self-Elevating Units." Det norske Veritas, Classification Note 31.5. July 1983.

(4) John O'R. Breeden of Friede & Goldman, Ltd. "Safety Management of Offshore Operations on the Canadian East Coast – Drilling Structures – Design and Construction I" Memorial University of Newfoundland,
Calgary, June 1983.

(5) S. Sengupta and John O'R. Breeden of Friede & Goldman, Ltd. "A Method for Punch Through Proof Design for Independent Leg Jack-Ups" Gulf/Texas SNAME Section Meeting, April 22, 1983.

COMMENTARY ON PAPER C1

T. Haavie
Managing Director
Submarine Engineering

Mr. Michel has presented a very interesting paper. In his treatment of a number of important design issues, I recognize the same situations of decision making as I have found myself in over the years. In most cases I agree with the reasoning. My contribution would be of little value, however, if I were to go through Mr. Michel's paper and, point by point, agree with him. Therefore, I shall try to express some different views on some issues, and make some additional points within the minutes I have at my disposal.

GENERAL STRUCTURAL CONSIDERATIONS (SEMISUBMERSIBLES)

I would like to present some alternative reasoning with regard to the global configuration of semisubmersibles; since the early days of semisubmersible design, units with two pontoons and four, six, or eight columns have been presented and built. It appears to me that one could argue as follows:

1. The larger the requirement for deck carrying capacity, the larger the units become.
2. The larger the units become, the more support points for the decks and superstructures will be required to keep the weight of the deck structure as low as possible.
3. Support points can be provided by columns and/or by trusses in vertical planes.
4. Trusses in the vertical planes are collision-prone items, and they do not provide any significant contribution to vessel stability. On the other hand, they are low in weight and effective frame stiffening members.
5. Connection between trusses, and between trusses and columns are well known "trouble areas" on semisubmersibles.
6. Trusses in the horizontal planes are basically tying the column footings or pontoons together to form closed frames. Their presence reduces bending moments in the deck structure. Such transverse trusses have low positions of centre of gravity, and their presence generally allows for a lighter deck structure than if they were not incorporated. In my opinion they represent well-spent material. They are, of course, of some magnitude and liable to dynamic loadings and possibly local slamming during transit in waves. Diagonal trusses in horizontal planes are generally incorporated to resist longitudinal misalignment between the pontoons. They are often termed "shear trusses", and as such take shear which would otherwise have been taken up in the deck structure. If the semisubmersible is relatively large, and particularly if the deck structure is "skinny", I consider such trusses as material well-spent.
7. A full deck box design, if sensibly composed, represents a strong bridge structure between the column tops. It is possible, and essential, that the column tops are given a good connection to the bulkhead and girder system in the deck box. A full watertight deck box design will have the following advantages:

- It provides valuable buoyancy in the case of damage.
- Its presence, with its inherent shear and bending strength, has justified the absence of vertical diagonals in longitudinal planes.

In the case of small semisubmersibles, this means the removal of the horizontal diagonal shear trusses near pontoon level, and in some cases of large semisubmersibles, the removal of the vertical plane diagonal trusses in the transverse plane. In other words, the designer may have an opportunity to compose a weight efficient semisubmersible with a minimum of collision-prone items passing through the air/water interface.

The watertight deck box, in our opinion, represents a valuable life assurance against capsize and sinkage.

STABILITY CONSIDERATIONS (SEMISUBMERSIBLES)

Again, one may return to the basic choice of vessel geometry. Watertight deck box or not, the damage stability property of the semisubmersible is very dependent upon the number of columns chosen. Let us take the example of the loss of buoyancy of one column at the maximum operational draught of three different semisubmersibles, and see how each unit reacts. Before we start, it may be useful to have in mind that if one considers one column to be flooded on three different semisubmersibles of the same weight, weight distribution, displacement and column heights; one with eight columns, one with six columns and one with four columns, then the resulting equilibrium angle would be largest on the four column unit and smallest on the eight column unit. By adjusting column heights, (assuming all the vessels to have a watertight deck box configuration), the result can, however, be

influenced considerably:

1. P099 Drilling Unit, 8 Columns. One column flooded when at operation draught. Angle of heel/trim: approximately 20 degrees.
2. MSV Stadive, 6 Columns. One column flooded when at operation draught. Angle of heel/trim: approximately 18 degrees.
3. P007 Design, 4 Columns. One column flooded when at operation draught. Angle of heel/trim: approximately 16 degrees.

As can be seen, the watertight deck box and the harmonization of column heights give reasonably small angles of heel/trim even in the case of extreme damage to any column of a four column unit. Even lifeboats can be launched, provided the wave conditions are not too extreme. However, if the vessels become large, then four column units will readily experience combined angles of heel and trim, subsequent to such damage, in the order of 27 to 35 degrees.

METACENTRIC HEIGHTS
(SEMISUBMERSIBLES)

In our opinion the minimum GM values presently proposed by regulatory bodies are far too lenient. Here are some reasons why we believe that the calculated GM values of a semisubmersible, in any condition, should be greater than 1.5 metres: it is well known that "ghost loads" of 200 to 400 tonnes are sometimes noted onboard semisubmersibles. Speculation as to the source of this unaccountable weight difference between displacement, arrived at by calculation of lightship, deckload, ballast water, fuel oil, consumables, etc., and displacement deduced from hydrostatics based on draught mark readings, has centred on weight growth and unidentified items onboard. Such loads are undoubtedly part of the "ghost load", but other factors could be equally important.

1. The compression of the lower hulls with increase in draught (resulting in less buoyancy, and therefore a deceptive impression of the ballast water needed to achieve a given draught; that is to a false impression of a lower KG value than the actual, and also to a higher GM value), calculations of the lower hull compression effect showed that plate field deflections (midfield) in the pontoons were in the order of 1mm on the *Ocean Ranger*, and panel deflections in the pontoons, between webs of the order 0.2mm (both values referred to hydrostatic pressure at about 20 metres water depth). It was estimated that this effect together with the welding effect (hungry horse effect) could account for a shrinkage in the order of 40 to 50 tonnes at the deepest draught. For a vessel of the size of the *Ocean Ranger* this shrinkage would have only a marginal influence on the GM value. However, for smaller semisubmersibles with thinner plates, but approximately the same frame spacings and the same draughts, the effect could be more radical, and could possibly become significant. This is therefore an item which should be borne in mind as requiring a margin when stipulating minimum calculated GM values for semisubmersibles.
2. The inaccuracy of tank soundings even in calm water conditions when the tanks are either thought to be empty or full. It is felt that the inaccuracy of tank sounding also may have a significant influence on the accuracy of the results from inclining experiments. Bearing in mind that a five percent overestimation or underestimation of the content of each full tank in the *Ocean Ranger* could represent a weight difference of the order 600 tonnes, this may be appreciated. In order to control such errors in a better way and hopefully be able to reduce them, it is proposed to carry out inclining experiments on at least two different draughts (with radically different tank contents), and also an additional displacement/draught test on a pontoon draught. The above effects could, even before delivery of the vessel, lead to an erratic basis for future assessments of KG or GM values.

During operations further errors will inevitably occur which would justify reasonable GM margins:

1. The uncertainty of any deckload weight assessment onboard a semisubmersible unit in operation;
2. The inaccuracy of tank soundings, particularly in a seaway with the vessel normally in a slightly heeled or trimmed condition;
3. The fact that many ballast control room operators do not like to "press up" tanks, and a full tank to the operator is usually a tank which is gauged "full", considerable volumes are often left as air pockets. The significance of this can best be illustrated by the underestimates of the tank content in a tank 10 metres x 14 metres. If 0.3 metres between liquid level and tank top is not filled, this is equivalent to approximately 45 tonnes underestimation if the tank is assumed full. This could be approximately four percent of a tank volume. The fact that a tank sounding of a "full tank" is usually different after some minutes (settling effect) also adds to the uncertainty.

Therefore, if the calculated GM value of a semisubmersible is, say, 1.5 metres, then it may well be that a unit actually only has a GM value of 0.5 to 1.0 metres. The dangers of such low GM values are now well known and apart from the vessel's failure to actu

ally meet the present rules, the following effects could endanger the vessel:
1. The wave induced tilt phenomena which are most pronounced at low GM values, and can cause substantial angles of heel;
2. The possibility of experiencing a reduced static GM value due to dynamic effects;
3. The variation in wind heeling moment effects causing frequent use of the ballast system for changes in the wind speed and direction.

CLOSING REMARKS

It could be said that the NMD damage stability requirement pertaining to the loss of buoyancy of one complete column is as unreasonable as asking an aircraft designer to design a fixed wing aircraft which shall be able to fly even when it loses one of its wings. It is, however, our opinion that the basic idea of a requirement for reserve buoyancy is a sensible one, but care should be taken not to attempt to link such a criterion to any form of realistic "high energy impact" damage. If this is done, energy considerations may lead to far too complex, selective and unrealistic calculations.

The criterion of reserve buoyancy should remain a "reserve buoyancy" criterion and be incorporated in any design as an extra safety against unlikely damages resulting from acts of God, collision with rocks, reefs, other large floating or fixed units. Such damages are usually considered as so unlikely that they will not occur. It is possibly appropriate to compare this with the improbability of collision between two aircraft, and also in this connection, to remember the fatal collision between two aircrafts on the ground in Tenerife some years ago.

The specified "volume of one column from lower deck level to top of pontoon level" also seems to give a sensible measure for reserve buoyancy. The advantage of stipulating the reserve buoyancy in terms of volume of one column instead of, for example, as a percentage of the total displacement volume are:
1. It prevents designers from designing semisubmersibles with four columns (or less) unless they take comprehensive measures to reduce the consequence of losing *one* of the few "stability" – and "structural" – main "supports". Vessels with six or more columns have a distinct advantage with respect to compliance with the rule. This seems to be a justified advantage, since the consequence of serious damage to the most damage prone items of a semisubmersible (the columns and vertical braces) is reduced with an increase in number of elements.
2. The location of corner columns is the most unfavourable part to lose buoyancy on a semisubmersible unit. The "one-column-flooded" criterion does therefore also provide a suitable moment imbalance for the buoyancy to counteract.
3. The definition of the reserve buoyancy as equivalent to the volume of one column from the lower deck level to the top-of-pontoon level provides a simple, clear, and undisputable criterion which cannot be misinterpreted. It has also been shown that most semisubmersible configurations, by sensible design, can be made compliant with such a criterion.

However, I also question, as Mr. Michel does, the "magic number" of 35 degrees.

COMMENTARY ON PAPER C1

W. Martinovich
Executive Vice-President
Earl & Wright

Mr. Michel's paper provides an excellent overview of design principles and processes for safe operations offshore as practised by the firm of Friede and Goldman. In general, I agree with most of this paper. The main feature, in my view, is the consistency in approach developed over the years and the application of this approach in a professional manner to the design of MODUs.

There are a number of points on which I do not agree with the author, but for the most part, they represent professional differences of opinion which in the end, whether practised consistently by his firm or mine, would result in a safe design.

I would like to make some remarks on a number of points which were either not fully discussed because the scope of the paper was rather large or about which I am particularly concerned and to which I wish to expose this conference.

SEMISUBMERSIBLES

Intact Stability

The present method of calculating intact stability is ridiculous. Considering that we are in a highly technological era of the late 20th century, what is in current regulations is a joke. We continue to try and accurately calculate wind overturning moments under the unrealistic condition of a flat ocean and an unmoored unit, when we know that motions are caused by waves, not wind, and that an intact semisubmersible of the type in use today cannot be capsized.

Other serious flaws in current rules are the definition of downflooding and the use of deck buoyancy to meet stability requirements. Most buoyant upper hulls are watertight in theory but not in practice, prime examples being the *Ocean Ranger* and the *Alexander Kielland*. When used to satisfy stability requirements, upper hulls generally are not designed to resist local forces due to waves, and that includes slamming.

In summary on this point, I believe a rational intact stability rule, as suggested in a statement (which follows this commentary) adopted by SNAME Panel MS-3 on May 7, 1984, along with explicit requirements for water and weathertightness and realistic structural requirements for buoyant upper hulls, is required.

Damage Stability

Damage stability is a real problem with respect to defining a credible event causing loss of buoyancy. Since the issue is primarily subjective, there can be as many different criteria as there are regulatory organizations. I look forward to the day when there is a reasonable, worldwide consensus of agreement on damage stability requirements. The limiting angle of 15 degrees mentioned in Mr. Michel's paper may not be a reasonable requirement. At Earl and Wright we believe a unit that relies on meeting the damage stability requirement by providing a generous gap between the operating waterline and the deck and lists slightly more than 15 degrees is inherently safer than a unit which has minimum gap and relies on an upper hull of questionable watertightness and strength to limit its angle of list. As with intact stability rules, we question the use of wind overturning after damage in defining limits of submergence. We believe that providing some freeboard or allowing some angular motion, or an error in GM to determine an allowable final waterline below downflooding after damage would be more rational. We agree with Mr. Michel and totally reject as a reasonable criterion the loss of buoyancy of a column as required by Norwegian regulations. The clever designers are meeting this requirement by providing deck buoyancy through an upper hull which can be made watertight in theory, but not in practice, and which is not designed to withstand wave forces. The end result is a false sense of security.

JACK-UP UNITS

With respect to the jack-up type of unit, I believe the concerns expressed in the paper about extending the experience beyond a 300 foot water depth are very real. In fact, I am surprised that there have not been more incidents of fatigue failures in deep water units that have been designed without considering dynamic amplification of motion and with questionable fatigue criteria.

RISK ANALYSIS

On risk analysis, I wholeheartedly endorse the position of Mr. Michel's paper on the subject and recommend that conference participants who are interested in the subject, study the Part Two Studies paper by Ian Burton on the subject.

INTACT STABILITY ON SEMISUBMERSIBLES

A Statement Adopted by SNAME Panel MS-3
Mobile Ocean Platforms
May 7, 1984

The SNAME Panel MS-3 (Mobile Ocean Platforms) takes interest in the several ongoing investigations into the above subject and wishes to make several observations and comments. It is hoped these comments will be considered when deciding the scope or direction of research and when drawing conclusions. They are offered in a constructive light, and represent the opinion of a cross section of designers, operators, owners, regulators and builders of semisubmersible vessels.

1. The present intact stability criteria for semisubmersibles which have been adopted by regulatory bodies worldwide are empirical. They are adapted from criteria developed for ship-shape vessels. At sea, experience has cast doubt on the absolute validity or applicability of the criteria. This situation is now being addressed; there is tremendous interest in developing meaningful, rational, and practical criteria.

2. A large amount of evidence is available from which assessments of intact stability of semisubmersibles can be made. This consists of about 20 years of operating experience, model tests and analytical work. If no damage, flooding or internal weight shift occurs, the records shows no stability casualties, and model tests have not been able to cause capsize, to the best knowledge of the panel. This is considered as ample evidence that the intact stability of contemporary semisubmersibles exceeds that necessary for safe operations.

3. This observation leads the panel to conclude that for contemporary semisubmersibles, it is likely that no intact stability criteria are necessary other than a minimum practical metacentric height. This is to say that, were a rational criteria written and applied, it should be satisfied by any contemporary semisubmersible with specified minimum practical GM.

4. The panel anticipates that current research efforts will culminate in conclusions similar to the above. If so, the task of setting down criteria reduces to one of defining limiting proportions for semisubmersibles of "normal forms" and "normal righting arm features" for which no criteria other than a minimum practical GM are necessary.

It is hoped that those engaged in stability research for semisubmersibles will allow for the possibility that their work may culminate in no criteria, rather than new criteria. A preconception that some criteria are necessary (other than minimum practical GM) should be avoided.

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Sonat Offshore Drilling

Paper C2 was written by A.M. Koehler, D.R. Ray, and A.A. Broussard. Mr. Broussard, who presented Paper C2 on behalf of its three authors, holds a Master's degree in Civil Engineering and has worked with Sonat Offshore since 1975. After serving as Manager of a number of Sonat's divisions, he was appointed in 1984 as Manager of the Research and Development Division. Mr. Broussard is a member of the ABS Special Committee on MODUs and the DnV Advisory Committee on Offshore Technology.

PAPER C2

Critical Systems and Continuity of Engineering Responsibility

This paper will consider the design of critical subsystems and the extent to which human engineering considerations are among the design criteria applied; and the importance of ensuring the continuity of engineering responsibility through the successive phases of rig design, construction, licensing, and operation. These two areas will first be addressed separately. Then the important feedback contribution to critical system designs due to engineering continuity will be highlighted.

Sonat Offshore Drilling, formerly The Offshore Company, has been involved in the design, construction and operation of mobile offshore drilling units since 1954. During this 30 year period, Sonat has designed and operated jackups, drillships, and semisubmersibles, participating in and contributing to the design evolution of the industry. This participation has included development of criteria and requirements for operating in deeper water and more remote, hostile areas. We are currently in the final stages of design of two fourth generation winterized semisubmersibles. The concepts discussed in this paper are drawn from these years of experience in the design and operation of MODUs, as well as from the background technical reports which have been prepared for the Royal Commission.

DESIGN OF CRITICAL SYSTEMS

"Critical systems" are those systems whose failure to function totally or in part could lead to the loss of the MODU or endanger the lives of those on the unit in credible adverse circumstances. This definition is the study basis used by Det norske Veritas (Canada) Ltd., in a report prepared for the Royal Commission which identified three of the systems most critical to the safe operation of MODUs. The selection of these most critical systems was based on DnV's assessment of the accident history of the mobile drilling industry, combined with the judgements of knowledgeable industry experts. According to this report, the most critical systems are:

- Stability/ballast systems of semisubmersibles
- Towing/transit systems of jackups
- Well control systems

Human engineering considerations are taken to mean the conditions, controls, limitations, etc., imposed on the configuration and functioning of a system by the fact that the system will be operated by men. Most human engineering considerations are universal, regardless of the purpose of the system. Therefore, for illustration purposes, these concepts will be discussed as they apply to the ballast system of a semisubmersible.

For critical systems, human engineering considerations must include the condition of the unit or system after the occurrence of a postulated incident. This may be a collision, fire, structural failure, or blackout. The incident may result in extreme inclination of the vessel, the presence of smoke or gas, flooded compartments, or power failure. The design criteria for the critical system must include redundancy, accessibility, ease of operation, minimum use of ancillary equipment, and self-diagnostics. Components of critical systems must be failsafe, foolproof, and field proven.

A fundamental design requirement from the standpoint of human engineering is that a critical system be configured for ease of access, inspection, testing, and in-service maintenance. Routine inspection, testing, and maintenance must be possible without interrupting the normal operation of the unit. This requires that the system be redundant so that individual functions can be performed with certain components out of service. The system must be subdivided so that malfunction in one area does not cause failure of the entire system. It must be possible to isolate subsystems or individual components for maintenance, testing, or repair without disabling the entire system.

If access is required to activate an emergency back-up function, then access must be humanly possible and reasonable after the occurrence of the postulated emergency. Further, to be meaningful, the access must be within a reasonable time frame. For ballast control, this requires that if certain ballast tank valves are designed to be manually operated as an emergency backup, then these valves must be within easy reach (not located under floor grating) and operable. It must be possible within human capabilities (physical and psychological) for a crew member to move down the column and into a pump room to easily reach the specific valve with the proper tools and equipment to operate that valve. In addition, there must be a positive indication on that valve of the position of the valve.

The controls of a critical subsystem such as the ballast system must be designed and configured to allow in-service troubleshooting. A malfunction in the system must not disable the entire system, and alarms and indicators must be provided to allow the fault to be located and remedied in a

reasonable time frame. To minimize distraction of the ballast control operator's concentration when responding to an alarm condition, the alarm system should have an effective alarm silencer. When the audible signal is silenced, the indicator for the source of the alarm should go from continuously lit to flashing. Any additional alarm after the alarm silence is activated must retrigger the audible signal.

For a system to be in good working order and available for activation in an emergency or critical situation, it must be routinely maintained and tested. Hence, its access must be convenient and designed to minimize the effort required for inspection and testing. It is an established requirement in the industry, for example, that all void areas on a semisubmersible be inspected monthly. However, on some existing designs, it may take several days and many manhours to perform such an inspection. The more difficult and time-consuming the inspection, the more likely that in operation the inspection will be delayed or cut short. Therefore, one of the prime considerations in the design of any subsystem is ease of inspection and maintenance.

It is desirable that any equipment required for response to an emergency situation be used during normal routine operation as well. This will maximize the potential for the equipment to be in good working order if an emergency occurs. If it is necessary to use a specific ballast pump to compensate for accidental flooding or damage, then this pump should be used for the same tank action in the normal operation of the vessel. If certain tanks of a vessel are configured so that a submersible pump would be used to empty that tank during damaged situations, then that submersible pump should be used routinely to ensure that it is in good working order and available for such service. A unique emergency response system to provide redundancy and backup for the primary system is also necessary. This system should be routinely tested and maintained.

In general, all critical systems should be designed and configured to allow routine maintenance without interrupting the normal operation of the unit. Procedures that require shutdown of drilling operations may be put off to minimize the impact on the operation, causing an adverse effect on the overall safety level of the unit.

CONTINUITY OF RESPONSIBILITY

Responsibility for human safety in offshore drilling activities extends from the host government that utilizes these services for resource development to the individual worker on the rig. Each of these several contributors, which include government authorities, operators, owners, classification societies, insurance surveyors, industry associations, joint governmental agencies, and crew members have the potential to support engineering continuity. This support can range from governmental rule making, to industry technical advances, to beneficial design feedback by a well trained crew. Through cooperative effort, the industry can safeguard its most valuable resource, its workers. As a preamble to the discussion of assuring continuity of engineering responsibility, the major contributors are acknowledged:

1. Government. Laws, rules, regulations, and standards established by governments to control the offshore operations in their country must be based on the principle of safety. These controls must not place the safety of the operation in jeopardy. As an example, the establishment of a quota on national crew members must also require a minimum level of training of these persons. Assurance of fully qualified nationals is the government's responsibility.

2. Operator. Operators should be required to conduct their operations in a manner consistent with the philosophy defined by the rules, regulations, and laws of the government. This means they must be responsible to select a rig and contractor which satisfy all the safety requirements; rig selection can not be based just on the lowest day rate. Operators must not compromise safety for the sake of money and should not contract a rig that is unable to safely conduct the operation.

3. Owner. The owner should never offer a rig for a job unless he is certain that the unit can safely conduct the operation from the point of view of the design of the unit and the qualifications of the crew. The owner is responsible for ensuring that the crew members are well trained, know what they are supposed to do, and are capable of doing their job. The owner is responsible for ensuring that subsequent changes and modifications to the unit and methods of operation after it goes into service do not result in a reduction in safety.

4. Classification Society. The classification society is responsible for seeing that a unit is designed, built, and maintained in accordance with latest rules. Since rules are periodically revised to improve the safety of the unit and could change during construction, the design and construction of the unit should be changed to comply with the revised rules. The society should ensure the use of good engineering practices in all aspects of design and construction. Problem areas not specifically covered by the rules should not be ignored.

Since the society is paid indirectly by the owner through the builder, conflicts of interest may occur. The societies should be more definitive about what is included in class in terms of the work they provide. Owners should realize that the society's representatives are surveyors, not inspectors. These surveyors are basically making spot checks to ensure that the manufacturers apply proper quality control, and do not necessarily continuously monitor the manufacture of components such as chain nor the construction of the unit. Wide variation of services provided by the different societies may exist.

5. Insurance Surveyors. Insurance surveyors are responsible for ensuring that the criteria applied in evaluating the suitability of a unit to work on a given location are safe and consistent from unit to unit. They usually have very little impact on original design.

6. Industry Associations. Industry associations such as API, ASME, and others are responsible for assuring the standards of quality and workmanship implied by their monograms. Manufacturers and suppliers should be routinely monitored and audited.

Associations such as IADC should be supported in their efforts to provide an effective forum for the exchange of ideas and the development of training standards.

Continuity of engineering responsibility through the successive phases of rig design, construction, licensing, and operation is fundamental and essential. It is generally accepted that the owner is responsible for licensing and operating a rig. He must also be fully accountable for the design and construction, although he may delegate all or portions of these responsibilities to qualified designers, builders, and classification societies. Continuity through all of these phases can be guaranteed only by the owner and is therefore the owner's unique responsibility.

Engineering responsibility from concept throughout the life of a mobile drilling unit can vary widely depending on the history of the particular unit. In the simplest case, a unit is conceived, designed, constructed, licensed, operated, modified, and maintained under the control of a single entity. An example of this is the drilling contractor who provides a full range of mobile drilling unit development and use. At the other extreme is the complex case where the designer, the constructor, the operator may be different entities. In addition, the unit may be operated by several different companies throughout its life. In the simplest case, engineering continuity is ensured and rests with the owner of the unit. In the extreme case, with responsibility divided into various segments and among various entities, the assurance of engineering continuity is much more difficult.

In either case, a primary role in the successful life of a mobile drilling unit is played by the classification society. Only the classification society is assured of significant involvement in a drilling unit's development and application. This is an obligation to which the classification societies have responded effectively. However, there are certain weaknesses in this system that the industry must be aware of and respond to appropriately.

In general, classification societies have become involved in the mobile drilling unit business in response to the interest and need of the industry to have a set of uniform rules prescribing design procedures and operational guidelines. To a large extent, these classification rules have been developed by the joint efforts of representatives of the drilling industry acting with the society. This group, developing the rules in association with the classification societies, is represented by the designers, the constructors, the operators, representatives of national authorities, and many of the significant equipment vendors. Classification societies are self-governing bodies with rules developed through an interactive process with important input from all of the participants. This input results in a negotiated rule development process. The groups have generally tried to obtain a responsible balance between the vested interest of the various groups.

Unfortunately, classification is a competitive business. This competition for class services among societies somewhat weakens their position in developing and enforcing tougher rules. They must be responsive to the interested groups that not only help develop their rules but are the primary clients for use of their rules and services. It is essential that classification societies develop rules based on their specialized technical knowledge and experience in the field of drilling unit design and that these rules be applied uniformly and fairly over the whole class of worldwide drilling units. The lobbying efforts of various special interest groups must be judiciously weighed against the necessity for providing a safe and reliable product.

Additionally, the various classification societies at present have somewhat different requirements, and perhaps more significantly, a somewhat different approach to the task. It thus becomes an important responsibility for the owner to judiciously evaluate the choice of classification society on the basis of its requirements, procedures, and knowledge available. For the owner to choose a society on the basis of the lowest bid is as unacceptable as it is for an oil company to choose a rig on the basis of the lowest day rate.

Whereas a class society may review the design of a specific unit to a given design criteria, they do not have any input into the site-specific use of such a unit. That is, a unit may be classed by the society for a design criterion that may or may not meet the requirements for operation in a specific location. The actual application of a unit on site-specific basis has generally been left to the owner's discretion. To accomplish this, the owner uses the services of a marine surveyor. The marine surveyor must provide the basis and review on which the unit is insured for a specific location. There may be a significant difference between the opinions of the various marine surveyors as to suitability of a unit for application on the specific site. The marine surveyors must necessarily use the services of experts in the fields of meteorology and oceanography to establish the design recurrence storm levels for a specific site. Once the site-specific criteria are provided, the marine surveyor must verify the structural and operational adequacy of a unit. The evaluation of structural adequacy must be based on methods consistent with the original design approach for the unit.

One of the problem areas in the industry is the difference of opinions of the experts in developing the meteorological extremes for a given location, and significant variation can occur. It thus results that a given drilling unit design may be approved for a specific location by one marine surveyor based on the environmental criteria developed by one expert, whereas an identical unit would not be approved for the same location based on a survey by a different marine surveyor using the services of a different expert. Determining the appropriate environmental criteria on a site-specific basis has and continues to generate concern and confusion among drilling unit owners.

During the classification society's design approval and its subsequent engagement, the society gains a unique knowledge of the qualities of the unit. This knowledge is, however, not fully available to and sometimes not even within the area of competence of the marine surveyor. There is thus reason to investigate whether a redefinition of the areas of responsibility of the parties and a change of their modes of cooperation would make it possible to improve the very important task of approving a unit for a specific location.

There can be no uniform assessment of risk for a mobile drilling unit operating in a specific area until there is uniformity in the environmental criteria. This difficulty in locating drilling units in site-specific areas is especially troublesome for the jackup drilling unit. However, it appears that the least uniformity of site-specific environmental criteria exists in those areas. To the owner and designer of a mobile drilling unit, this creates a very perplexing problem in which it is very difficult to determine what environmental criteria should be selected for the design of a unit that will give it the greatest marketability and yet allow economic and region-specific design application. One approach which has been taken in the North Sea is that the regulatory body specifies the environmental criteria to be applied for certain areas of operation. In this case, a given drilling unit design can be evaluated against known criteria, and a level of risk can then uniformly be applied to all units considered for operation in that area.

As the industry moves into frontier operating areas such as Canada, it is essential that the industry develop some method of establishing uniform environmental design criteria that can be made available to designers, owners, and operators of drilling units so that the units can be economically configured and built for efficient, safe operation.

In general, rules and regulations are developed based on advances in technology, improved analytical techniques, or as in the case of the *Ocean Ranger*, in response to significant failures of concepts, equipment performance, or crew response. In each case, the intent of revision of the regulation is to provide safeguards against accidents or failures that endanger human life and the environment. They are generally developed by collective engineering judgement and often in response to industry-wide experience. As such, they expand the awareness of the individual designers and owners and thus represent an element of universal continuity of engineering responsibility.

Unfortunately, there exists a significant short circuit in this evolving process and that is the concept of "grandfathering." In principle, the practice of "grandfathering" is to minimize the sudden economic impact on the industry and, specifically, on individual owners and contractors, of restricting or denying operation of their units in specific areas. However, the result is that in a given operational area, there may be two rigs operating: one that has been designed to the improved expanded regulations and one that is allowed to continue to operate with some exemptions from full compliance with these regulations. It must be that the level of risk associated with each operation is different and in extreme cases can be extremely different. Therefore, the industry must question the concept of "grandfathering", unless it mandates a specific deadline for bringing an existing unit into full compliance with the new regulations.

This is a controversial issue; the designers and owners of an existing unit will generally take the stand that their unit's design has been safe enough and that the regulations

have been drawn up out of an overreaction to a specific occurrence or set of circumstances. It is argued that such an occurrence in isolation does not justify the regulations. However, the argument can be made on the other hand that while it is human to make an error or to be less than perfect in the evolution of an industry or design concept, it is negligent not to respond to the lesson that operating experiences teach. It is recommended that "grandfathering" be allowed only on a very limited basis and that a definite time frame be specified for existing units to be brought in full compliance with the new regulations.

Engineering design is an iterative process, progressing in stages of evaluation and revision. The refinement of each successive stage depends on the assessment of the previous stage. The process continues until the resulting system performs to a chosen standard of safety and reliability. The parties involved in offshore drilling from government to worker are interdependent and must rely heavily on each other for valuable input and feedback to refine system design and performance requirements. Each party is responsible for obtaining such input and providing necessary feedback.

The designer of a semisubmersible is responsible for the design of critical subsystems such as the ballast system. This responsibility does not end with the design but extends through construction and operation. The owner is responsible for the operation of the ballast system and the training of the ballast control crew; however, the designer must remain involved, giving procedural input and receiving performance feedback. Only through an assessment of operability and performance in practice can the design be evaluated and refined to provide greater safety and reliability.

The contribution of the government of Canada through this Royal Commission Conference in providing a forum for the exchange of ideas among the responsible parties is applauded. This will certainly promote a clearer understanding of the necessity of, as well as the difficulties involved in ensuring continuity of engineering responsibility through the successive phases of rig design, construction, licensing, and operation. We appreciate the opportunity to participate in this conference.

COMMENTARY ON PAPER C2

F. Atkinson
Senior Principal Surveyor
Lloyd's Register of Shipping

Dr. Koehler has enhanced the proceedings of this Seminar with a paper which covers a wide range of activity, examining the engineering responsibility of a number of large organizations concerned with the design, construction and ongoing operation of an offshore mobile unit. It is unfortunate, but true, that most advances in safety connected with the marine industry are the result of a tragic accident, and I have no doubt that, just as the *Alexander Kielland* contributed to enhanced safety, so the loss of the *Ocean Ranger* will improve the lot of the mariner involved with offshore activity.

It is impossible to look at any one organization and say with absolute certainty that any activity is entirely its responsibility. Design and construction of a mobile unit are governed by the wishes of an owner and the ability of the designer to respond to those requirements while at the same time producing a design which can be efficiently constructed by the builder. In turn, these three bodies must ensure compliance with the requirements of the classification society, the national government or flag state, international standards and a multitude of codes to bring about a successful unit.

Unlike conventional ships, where international regulations are paramount, mobile units must be primarily designed to the wishes of the government upon whose continental shelf the rig is to operate. Although various national regulations may be common in intent, there are a variety of differences which make truly international operation difficult. For instance, one only has to compare the requirements of the governments of Canada, the U.K., U.S.A., and Norway to highlight a number of differences, most of which are connected with the standard of damage stability. The way in which the rules are interpreted with regard to structural redundancy and boat impact damage emphasizes this point.

Although the environmental factor is part of the equation when the structural analysis is examined by the classification societies, I would suggest the setting of extreme conditions must rest with the government of the continental shelf state. Dr. Koehler tends to suggest that the classification societies do not have any input into the site location of a mobile unit, but this is not strictly correct. If a unit operates at a location where the environment, for either transit, operational, or survival modes, is outside of the prescribed conditions, then it is out of class.

In addition, if we, as a classification society, are acting as a certifying/verification agency, then the *Certificate of Fitness* applies specifically to a chosen area. Having said this, I would suggest that I would question Dr. Koehler's remark that once an area is chosen, the marine surveyor can verify the structural and operational adequacy of the unit. This can only be done by having an intimate knowledge of the unit.

As Dr. Koehler had indicated, it is unfortunate, but true, that the main factors concerned with the *Ocean Ranger* casualty would appear to be connected with the ballast system, the control mechanism to that system and the ability of the crew to operate it. This highlights the duplicity of control exercised over offshore operations and emphasizes perhaps the need to have more stringent international, or at least national, statutory requirements.

The human activity that takes place on an offshore unit is considerably varied, depending on its mode of operation. Such a variety of interests and disciplines must lead to a dichotomy of responsibility and emphasizes the need to have a fully trained and competent crew with someone in absolute authority at its head.

Although mentioned by Dr. Koehler, I do not think that significant emphasis has been given to crew training and it is a point this symposium may wish to discuss further – training in association with assessed and agreed levels of competency.

If one looks at any offshore unit, it can be seen that the end result is an amalgam of design aspirations, constructional limitations, stability criteria, inspection methods fraught with human fallibility, and the relatively limited requirements of certification, classification and quality assurance. These are further confused by the necessity of crewing such a unit and providing them with adequate lifesaving appliances, which will only be required under extremely harsh environmental conditions and at times of considerable stress and confusion.

I will turn now to the second part of the paper dealing with the continuity of responsibility, particularly as experienced during the life of a MODU. Historically, unlike normal marine activities, it is more common for designers to be involved with the eventual operation of a mobile unit. This pattern is slowly changing whereby the shipyards are now responsible for their own design, with the vessel being operated by a company detached from the designer. This trend breaks down the traditional continuity from the designer to drilling contractor, and with the influence of port state authority being exercised only over limited periods, I would suggest, in agreement with the author, that

the classification societies are the organizations involved with a particular unit over the longest period of time. However, it should be appreciated that, whereas the societies take a considerable interest in structural aspects and are tending to be more involved with stability, they cannot and should not be involved with crew competency. This is entirely a matter for the country of registration and the continental shelf state concerned.

In discussing the role of the classification societies, Dr. Koehler has raised three items worthy of discussion.

1. He suggests that rule changes which occur during the construction of a unit should apply immediately. This is contrary to all of our normal marine approach where rules only apply six months after acceptance and then only to designs introduced after that date. To accept the authors' proposal would introduce considerable contractual difficulties and would be completely unacceptable to the builder.
2. I would agree with the authors' suggestion that a grandfather clause should only be introduced on a very limited basis and then within an adequate time frame. Grandfathering has only been done on very, very rare occasions and I would suggest this is mainly the prerogative of governments, not Classification Societies, and even then on a gently, gently basis. It can be done, of course, and the audience's views on this would be welcome, but the considerable financial ramifications, although outside the classification process, should not be forgotten.
3. Dr. Koehler indicates that an owner may delegate all or part of his responsibilities. I would suggest that no owner can ever delegate all his responsibilities and, indeed, at the end of the day, he has ultimate responsibility, even though it may be shared with other bodies. I note the authors' remark on competition between the classification societies, but can not entirely agree with the implication that business may be bought at the expense of safety. I do feel, however, that all societies should be divorced from governmental authority, and protectionism should be deprecated.

I think that both this Conference and Dr. Koehler's paper have indicated a need for a stricter control over the design and operation of mobile units. Whatever changes are made, however, should be technically justified and not the result of emotive changes to satisfy public conscience. I would suggest to this audience that it is not the great momentous changes which will influence the future safety of mobile rigs but greater attention to detail, during both the design and construction of future rigs.

I would like to thank the Royal Commissior for the opportunity to expound these views all of which may not directly relate to Dr Koehler's paper but which are complemen tary to them and should ensure a wide rang ing discussion aimed at enhancing th safety of offshore mobile units.

COMMENTARY ON PAPER C2

M. Vermij
Engineering Specialist
ASE, Transport Canada

Since my background is not directly related to marine safety, but rather to aviation safety, I will restrict my comments to the experience I had with the *Ocean Ranger* accident investigation and the wreck's safety analysis issues.

First of all, I would like to have a look at the definition of critical systems, as it was described in Mr. Broussard's paper, and I would like to make an addition to that. The paper stated that critical systems are those systems whose failure or function in part or totally may lead to a loss of the rig and endanger the lives of those on the unit in credible, adverse circumstances. I would like to add that it is also the improper operation of a critical system, as is evidenced in the analysis of the *Ocean Ranger*, which may lead to a loss. Also, the words "credible, adverse circumstances," from a safety point of view are really not necessary. The definition of engineering continuity I could not find in the paper, and I made up my own. I would like to submit it for discussion and see if it is a correct or a desirable definition: "the creation and maintenance of an operational line of communications, mostly to the crew, reaching sure, proper and safe operation, monitoring and maintenance of the rig's critical systems in all possible conditions throughout the service life of the unit."

From being involved in the *Ocean Ranger* disaster analysis and reading through the Part One Report, I added something like twenty-two causal factors that led to the sinking of the rig and the loss of the lives of the crew. Seventeen of these causal factors caused the sinking of the rig and if any one of these factors were changed, the disaster would probably not have occurred. As you can see, six of these factors are directly caused by engineering discontinuity and twelve are directly related critical systems failures. This display has the purpose of giving some meaning to the concepts of critical systems and engineering continuity. As a lesson from the *Ocean Ranger*, I would consider it an important design principle to include detailed fault tree analysis as a design and safety tool, preferably performed by an independent facility and maybe be presented to the designers on a quasi-adversary basis.

There are two points in Mr. Broussard's paper with which I did not quite agree. One is where it was stated that, "if the engineering responsiblity was solely due to the simple case of where the design, construction, operation and modification and control came from a single unit, then the engineering continuity is ensured and rests with the owner of the unit." I do not quite agree with that. I think the responsibility in this case is quite clear, but engineering continuity is certainly not ensured just because there is a single owner and designer. The engineering continuity requires a continuous effort by the parties concerned to maintain it and to keep the crew, etc. properly trained to manage the ship properly.

The other point I would like to make relates to the comment that, "The establishment of a quota on national crew members must also require a minimal level of training of these persons and assurance of fully qualified nationals is the government's responsibility." I do not think that just because the operator has an agreement with a particular government that he can transfer the responsibility of crew training.

That is about all the comment I have. I thought it was an excellent paper and I had great difficulty in finding any discrepancies. Thank you very much.

A	B	C	D	CAUSAL FACTORS (*Ocean Ranger* Disaster)
■				1. Severe Storm
■				2. Wave and Wind Direction
	■			3. Location of Ballast Control Room
	■			4. Portlight Strength
			■	5. Position of Deadlight
	■			6. Water Resistance of Switches
	■			7. Electrical Control of Pneumatic Valves
		■		8. Independent Valve Status Panel*
	■		■	9. Switches Failsafe Wiring
	■			10. 24 and 115 Volt System Proximity
			■	11. Panel System Intervention by Crew
	■		■	12. Tank Level Monitoring System
			■	13. Manual Valve Operation by Crew
	■			14. Draft Monitoring System
	■			15. Ballast Pump Location
	■			16. Tank Piping System
		■		17. Chainlocker Deckholes
		■		18. Chainlocker Drainage
		■		19. Vent and Stairwell Deck Holes
			■	20. Evacuation Timing
	■			21. Evacuation System
■				22. Low Temperatures
	■			23. Protective Gear

Environmental Factor — **C** 'Non' Critical System Failure
Critical System Failure — **D** Engineering Discontinuity

he lack of an independent valve status panel cannot be considered a causal factor.

Summary of General Discussion Following Papers C1 and C2

There was considerable debate throughout the discussion period on the matter of classification society design rules for MODUs, how they are compiled and then applied, and the effect of rule changes on existing and in-progress units. Mr. R.E. Johnson (NTSB) criticized the lumping together of stability requirements for semisubmersibles, jack-ups, and drill ships, as the forces and responses affecting each type are significantly different. He felt that most research to date on the damage stability question has been concentrated on the semisubmersible type of unit. Although Mr. Johnson agreed that model testing could be a useful tool, he outlined the problems of accurately modelling the effects of green water on decks, of wave impact on deck structures, and of selecting appropriate wave spectra. He was also wary of the problems associated with translating test results into information which is relevant to the end user onboard a ship or rig. Mr. E. Dudgeon (NRC) advocated the use of simulations to ensure the accuracy of tests results.

With regard to the selection of appropriate wave spectra, Mr. L. Draper (Institute of Oceanographic Sciences, U.K.) responded that it is not possible to apply one standard wave spectrum in all model tests because each geographical region has its own distinctive energy spectrum.

Mr. W.H. Michel (Friede & Goldman) responded to Mr. Johnson's concern about stability requirements by re-affirming his contention that it is necessary to consider both wind and waves in establishing and applying stability criteria, and that designers should incorporate both model test results and theoretical calculations intelligently, in designing to compliance with stability rules.

Mr. Johnson disagreed with Mr. T. Haavie (Submarine Engineering) that a number of inclining tests should be carried out on any one rig design-type while it is still new, but Mr. Haavie emphasized the importance of obtaining accurate results and this, he felt, justified his argument that more than one inclining test be required, despite the high cost.

Dr. J. Pawlowski (NRC) addressed the need for research on stability, and endeavoured to place the issue in a broad perspective. The current design emphasis is on structural features. On the other hand, the loss of a vessel is always related to a loss of stability and flotation. Dr. Pawlowski emphasized the role of research as a forerunner to design in the building process, and it is the evaluation of the performance of the resulting design which confirms that the research process has been effective. Because a well co-ordinated research effort in this area does not yet exist, he urged research and regulatory institutions to combine their efforts towards a better understanding of the stability of floating structures and so provide designers with significantly more reliable guidance.

Mr. V. Greif (SEDCO, Inc.) commented on two aspects of Mr. Broussard's paper: 1) the responsibilities of training personnel in regions which have local hiring policies; and, 2) the revision of design rules and regulations and the potential effect of "grandfathering" units. He submitted that it is the role of industry, not government, to hire and train local labour, with the proviso that imposed quotas should not create unreasonable pressures on the training effort. Mr. T.S. McIntosh (IADC) added that, where quotas are set without consideration of the availability of qualified workers and the requirements in the training of unskilled workers, the government setting the quotas assumes a portion of the responsibility of providing training, even though that responsibility may be delegated to industry.

Mr. Greif then spoke with reference to upgrading existing units as rules and regulations evolve by pointing out that most units have operated successfully over many years without accidents and without the incorporation of major changes, so there is no justification for the automatic retiring of those units which do not comply with the most recent rules. He said that, in most cases, prudent owners do upgrade their rigs when rule changes are critical and when the changes are deemed beneficial. This, of course, assumes that the change is both feasible, and, as well, that it does not adversely affect other aspects of the unit. Mr. McIntosh added that Zapata Corporation does incorporate any rule changes during the design and construction phases of a unit, which are justified to increase the unit's reliability or level of safety.

Mr. F. Atkinson (Lloyd's Register of Shipping) pointed out that not all rule changes are of equal significance or of fundamental importance to rig safety, and therefore it is important to evaluate carefully the changes before creating contractual and financial difficulties by requiring changes in a unit already under construction. Mr. Broussard (Sonat Offshore Drilling) disagreed that not all rules should be incorporated, even if a unit is in midstream, because owners usually demand that new units comply with all the most current rules, not just those selecte as most relevant to that particular design.

Mr. J. Hornsby (CCG Ship Safety Brancl then referred to the matter of responsibili for ensuring that a rig is appropriate ar safe for a particular function, regardless its compliance with rules. He maintaine that the flag state, because it administe the licencing of rigs operating in its jurisdi tion, assumes responsibility for ensuring tł adequacy of a unit. This is especially trı because the classification societies mainta a waiver of responsibility in their rules. M Hornsby then promoted the idea of workir through the International Maritime Organiz tion to establish international standards f MODUs, and Mr. I. Manum (Norwegi Maritime Directorate) agreed that such approach would be most appropriate.

Mr. Dudgeon suggested that if a MODU viewed as a complex, industrial syste then its operating behaviour must also treated as a system. He pointed to the u of models and simulations, both physi and computerized, as aids to syste analyses and design, and to simulatio being particularly effective as training to and in examining "what-would-happen- scenarios.

Mr. Nigel Hendy (Burness, Corlett & Pa ners) explained that model tests were us extensively in the course of the *Oce Ranger* investigations, and that the tests both NRC and NHL used a combination wind and wave loadings, as well as wi gusts. It was found that although wa forces predominated in the moored con tion in shallow waters, the effects of wi loads can become more prominent with change in water depth or changes in condition or type of mooring system. Hendy, in closing, agreed with Mr. Haavi comment that portholes, if unsatisfacto designed and operated, can place a unit risk in cases of extreme listing.

Mr. Ray Street (Hollobone, Hibbert) qu tioned the thrust of research into the an ysis of structures and their stability in light accident statistics which indicate that nc resulted from a failure of static stability seems more appropriate to expend grea efforts in examining and ensuring the re bility of systems, the failure of which see to contribute more often to accidents.

Mr. Michel defended the present conc tration on stability research and said tha is necessary to establish proper stability teria and to know their influence in m imum environmental conditions. Mr. Man also supported the importance of being a

to establish damage stability criteria, the knowledge of which could prevent capsizing and increase survivability. He felt that damage stability was an especially important consideration in providing sufficient time, when an accident occurs, to permit a unit's crew to mobilize the lifesaving appliances available to them. Without stability in a damaged condition, capsizing would probably occur before the crew could be evacuated safely.

Mr. G.L. Hargreaves (Consultant, U.K.) referred to certification, as opposed to classification, practices in the U.K. The sole authority for allowing exceptions to the rules is vested in the Secretary of State, and exemptions are approved only after consultation with the certifying authority and its advisors. In Mr. Hargreaves' experience an exemption is granted only with some compensating condition imposed to ensure safety of life. Mr. Manum said that in Norway the certifying authority is the Norwegian Maritime Directorate which is very concerned with damage stability criteria and works closely with the classification societies and their criteria.

3

MAN/MACHINE INTERFACE


Royal Commission on the
Ocean Ranger Marine Disaster
Commission Royale sur le
Désastre Marin de l'Ocean Ranger
Safety Offshore Eastern Canada

MAN/MACHINE INTERFACE

INTRODUCTION

In this area the major aspects studied were personnel training and equipment design with a view to reducing operator errors. This examination included consideration of current feedback mechanisms which provide equipment manufacturers with information from equipment operators and users which can be incorporated to improve equipment redesign. Personnel selection was also reviewed in order to identify the basic minimum qualifications for key positions on MODUs which require the operator to perform ancillary and/or emergency control functions.

This Technical Session was chaired by Dr. G.M. MacNabb, who holds a degree in Civil Engineering from Queen's University, as well as six honourary doctorates from Canadian universities. He spent his earlier professional years with the Federal Government, most notably as Senior Assistant Deputy Minister of Energy, Mines and Resources Canada to which he was appointed in 1975. Dr. MacNabb has been President of the Natural Sciences and Engineering Research Council since 1978, and is also President of Uranium Canada Limited, honourary Vice-President of the World Energy Conference, and Director of Atomic Energy of Canada Limited.

Dr. P. FOLEY
Head, Dept. of Industrial Engineering
University of Toronto

Dr. Foley has broad experience in human factors problems, and in 1966 he instituted the Human Factors Program at the University of Toronto, where he is currently the Head of the Department of Industrial Engineering. He has represented Canada on numerous international committees and is also member at present of a number of Canadian research and development committees.

PAPER D

Operator Competence in Relation to Critical Systems Technology

Given the time constraints placed upon me in the preparation of this paper, and the consequent lack of opportunity to familiarize myself with the specifics of the offshore drilling problem, I have decided to concentrate upon an examination of the general problem of the design of man-machine systems and the role of Human Factors Engineering in this context. There may therefore be some overlap between my remarks and those of other speakers. Any such repetition should be taken as emphasis rather than redundancy.

The design of a man-machine system is an attempt optimally to integrate the basic elements of such a system, namely, human, physical and informational resources, to achieve some clearly-defined goal. However, these elements are not independent and the design problem becomes one of decision taking where one has to consider not simple tradeoffs, but the possible effects of very complex interactions among the basic elements. Further, the decision taking process itself may be affected by possible implicit assumptions. Consider the design implications of the following assumptions, for example:

1. "If I design my equipment this way, what can I expect of the human operator, and what will the effectiveness of my system be?"
2. "If the human operator is to use his capabilities this way, how must I design my equipment so as to optimize system effectiveness?"

The difference between one and two may at first sight seem to be rather subtle, but it is, in fact, critical. The design implications are extremely profound, and the importance of making explicit what is implicit, cannot be overstressed.

Let us then examine the design problem in detail. Figure 1 shows the basic components of the system, the human element, the machine element and the information element. It also emphasizes that no system exists in isolation, but within an environment which subjects it, in both the design phase and the operational phase, to critical forces. I have listed the most obvious of these. Note that the order is simply alphabetical and consequently avoids the problem of deciding their relative importance. This is not an attempt to evade a difficult task, but a recognition that, for any given system, relative importance is itself one of the decisions to be made. The diagram also emphasizes that no element exists in isolation within the system. The human element affects and is affected by the machine element. The human element affects and is affected by the information element. The information element affects and is affected by the machine element. Most importantly, the design process affects and is affected by all three, and their interactions, both first and second order. These complexities require a highly structured approach and one such structure (Wulfeck and Zeitlin, 1962), is illustrative and still relevant. The layout is necessarily sequential, but some of the activities will of course be concomitant:

1. Establishing system goals;
2. Determining system requirements;
3. Allocating system functions between men and machines by:
   - determining information requirements
   - determining transfer requirements
   - determining control requirements
   - establishing a maintenance and logistics philosophy;
4. Equipment design and workplace layout;
5. Establishing manning requirements;
6. Determining training requirements;
7. Training;
8. System test and evaluation.

If this all seems like common sense, let me assure you, in the words of one of my former Professors, that "common sense is the scarcest economic commodity," a statement I have never found it necessary to qualify.

The point in which human factors input is required will, of course, depend upon the system goals. For example, if the system goal is to put a man on the moon to sort and gather geological specimens, then knowledge of human capabilities and limitations in a lunar environment will be required, to decide whether or not such a goal is realistic. If on the other hand, to continue the standard example, the goal is to develop a fully-automated system for geological exploration of the lunar surface, then knowledge of human capabilities will not be required until the point at which establishing a maintenance and logistics philosophy is reached. Parenthetically, it is interesting to speculate on the role of social and political environmental factors in influencing the determination of the goal of the Apollo missions, culminating in the achievement of *Apollo II* in 1969; given Sputnik in 1957, the Luna missions in 1959, and the formal inauguration of NASA in 1958.

In any event, although human factors input will be required in steps one and two, it is at stage three, allocating system functions between men and machines, that such input

Human

Personnel
- Anthropometric
- Biomechanical
- Sensory-Cognitive

Training
- Skill Acquisition
- Skill Maintenance

Reliability
- Human Error
- Safety

Design

Goals
Requirements
Allocation of Functions

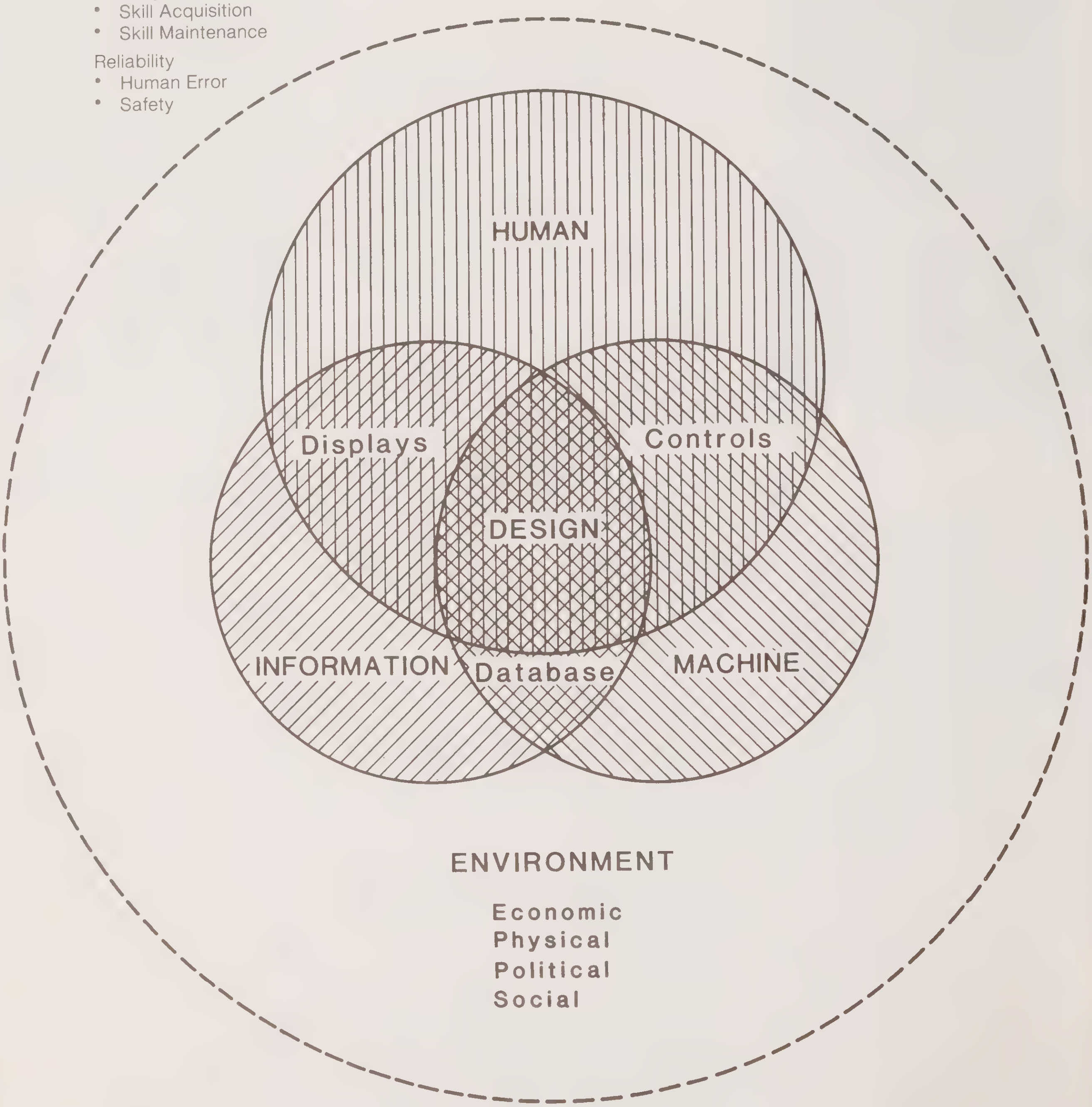


FIGURE 1 Human factors in the design of a man-machine system

of vital importance. Here considerably more than superficial understanding of the relative capabilities and limitations of both men and machines is required. Much effort has, in the past, been expended by human factors specialists in investigating, codifying and tabulating human performance characteristics culminating in the "Fitts" list and the more sophisticated modern version proposed by Geer, (1981). However, this approach is limited, concentrating as it does on the relative efficiencies of men and machines. The issue is never quite so clear. The question is not simply whether a man or a machine, but rather how they should interact. The rapid developments in the computer field have posed new questions, the answers to which are not intuitively obvious. Consider for example, the following description of interaction[1]:

1. The human does the whole job up to the point of turning it over to the computer to implement.
2. The computer helps by determining the options.
3. The computer helps determine the options and suggests one, which the human need not follow.
4. The computer selects action and the human may or may not carry it out.
5. The computer selects action and implements it, subject to human approval.
6. The computer selects action, informs human in plenty of time to stop it.
7. The computer does whole job and necessarily tells human what it did.
8. The computer does whole job and tells the human what it did only if the human explicitly asks.
9. The computer does whole job and tells the human what it did, and it, the computer, decides the human should be told.
10. The computer does the whole job, if it decides it should be done, and if so tells human, if it decides he should be told.

The ten possibilities listed are not by any means exhaustive. In each of the ten cases, the original human request may either not be necessary or be ignored by the computer. Step ten alone can have several variations, where the computer tells the human necessarily, or on his request. The ultimate condition is the dynamic case, where one does not decide initially exactly what the interaction will be, and that interaction is then built into the system and fixed, but rather that the form the interaction takes will vary from time to time, depending on the state and needs of the system, and this adaptability will be built into the system. In summary, allocation of function is critical in system design and development. Functions, having been defined earlier must now be given specific form; how, precisely, will they be implemented? It is obvious that the problem must be tackled in a systematic way. Each possibility must be examined and defined with respect to its information, transfer, and control requirements and of course to the system requirements. Only then can rational choices be made among alternative configurations. It should also be obvious that this is not a task for amateurs, nor is it something that can be tacked on to other responsibilities, nor can it be allowed to evolve. Human factors expertise at this stage is mandatory, and the human factors specialist should be a member of the design team. This should become clear as we examine the information, transfer, and control requirements in more detail.

Determining information requirements is not as simple as it may at first sight appear. Too much information is obviously as bad as too little. What then constitutes just enough? How much pre-processing of information can be entrusted to the machine to reduce information overload and simultaneously take advantage of the human's powerful pattern recognition abilities? The answers to these and similar questions will depend upon what role the operator is expected to play. Bainbridge (1984) reviewing studies of the performance of the human operator in process control, emphasises the need to "obtain information on the operators' understanding of the situation, intentions and expectations." Displays should show the structure of the process and focus on the level of process variables rather than the stage of plant components. The displays should use a format which supports the flexibility of the operators' thinking. It should be pointed out perhaps, that Bainbridge bases her recommendations on a detailed analysis of six nuclear power plant incidents, including Three Mile Island, using reports giving detailed post-event analyses, made with the operators, of what happened during each incident. Her report emphasises the need for a thorough understanding of human cognitive capacities and limitations before rational decisions about the information interface can be taken. As she rather wryly comments, and in this context it is worth quoting her in full; "Engineers looking for advice from ergonomists tend to ask for absolute numbers for performance levels. 'We don't want to know about cognitive processes, just tell us what is the human: error-rate/information transmission capacity, memory capacity, perception capacity, and we will design the system accordingly'."

Unfortunately, the task categories used as a basis for asking for such numbers are too simple. Suppose for example one asks for human failure rates in 'deductive reasoning'. Hunter (1959) found that the number of people who can say which is the biggest item in a '3-term series' problem, within a time limit, depends on the way the task is presented. For example:

$a > b$,	$b > c$	70%
$a > b$,	$c < b$	59%
$b < a$,	$c < b$	43%
$b < a$,	$b > c$	27%

If changing the order of the information can more than double the failure rate, then the detailed transformations that the person has to carry out to do the task have more effect on failure rate than the overall task of deductive reasoning. Detailed knowledge of the cognitive processes involved in a task may be necessary before performance predictions can be made with any accuracy. Since this knowledge precedes display design, I again, emphasize that this is not a task for amateurs.

Determining transfer requirements calls for similar understanding and a similar approach. Here the emphasis is on mathematical modelling of the performance characteristics of the human operator, and the potential ability to match operator characteristics with machine characteristics to arrive at a quantitative expression of the system dynamics. This approach has many advantages; the ability to make precise design comparisons, to predict performance, and to evaluate the adequacy of the design chosen. It does, on the other hand, call for fairly sophisticated techniques and considerable quantities of data, the human operator not being a simple linear system. The approach is, however, showing considerable promise, particularly in the estimation of mental workload, a notoriously difficult problem, and a very important problem. Standard physiological measures have so far proved to be not very helpful, in spite of considerable research effort. The approach taken by, for example, Moray (1979), is indicative of present trends. The area is becoming more and more popular, given indications that excessive mental workload may be the primary factor in operator error, and useful principles are emerging.

Control requirements can be tackled in a similar way, that is, by using mathematical models of the human operator, and the general principles outlined above, apply.

In summary then, the "allocation of function" is critical to system development, calls for highly specialised knowledge and understanding of operator characteristics, and

demands that such expertise be given equal weight at the design level. Retrofit is inefficient and very expensive.

Equipment design and workplace layout is an area where the problem is not one of complexity or insufficient research or lack of relevant data, but rather one of what might be called "information transfer". The data exist in abundance, in handbooks, textbooks, reports, giving all the recommendations one could ask for with respect to body sizes and dimensions for different populations; the dynamics of body movement; forces that can be applied in different configurations; sensory sensitivities and discrimination capabilities as they affect legibility, intelligibility, and so on. Perhaps there is too much information available, so that many designers simply give up and design for themselves. Examples of this are numerous and can best be demonstrated by a few pictures. The answer lies in the systematic approach to the design process, ensuring that at least the data required can be identified at an early stage. Even here one has to be cautious, as the recent Swedish-Finnish Saab incident demonstrates. Ergonomic design of work places was considered very important and the design was carefully tailored to the population characteristics. Unfortunately, the data were Swedish and the operator population was Finnish, quite different. Constant vigilance is required.

I shall deal with the problems of manning and training together, within the context of error and reliability, since they are intimately related. Here I would emphasize that the system development procedure I have delineated earlier, is only linear because of the constraints imposed by the print mode. I repeat that we are dealing with a highly interactive process. I would also emphasize that the design of a training sub-system is subject to the same process and constraints as the design of the overall system itself. What then is error? Senders (1982), discussing human error and human reliability, within the context of process control, distinguishes between those errors which arise from factors internal to the operator, endogenous errors, and those errors which arise from factors external to the operator, exogenous errors. Endogenous errors we attempt to reduce by selection, training, and practice, and exogenous errors by "good design". The point here is that although we do not as yet fully understand the fundamental nature of error, we can still tackle the problem of error reduction. As Senders points out, "it is clearly beneficial to select people who can grasp the controls, see the displays, read the numbers, understand the language, and so on. It is clearly beneficial to tell these people what to do, i.e., train them in the system. It is clearly beneficial to design the displays and controls and the panel layout in such a way that they are within the grasp of one or a team of human beings. Beyond that, however, the simplistic assumption of linearity that tells us if we made all parts good, the whole will be good, is unproven." Since training can reduce endogenous errors, then let us give careful attention to training, even though our imperfect understanding of the genesis of error does not allow us yet to decide what is the optimal training system, having regard to efficiency. Remember that process control is no different from any other kind of skilled performance; to become adept we must practice, practice, practice, until performance becomes essentially automatic, "open-loop". This surely is the essence of all skilled behaviour, that we do not have to consider the individual components; in fact to do so is counter-productive. As Schrodinger once said, "consciousness is becoming, unconsciousness is being." We may not indeed be able yet to optimize, but we can at least meliorize. And we can improve performance by logging and analyzing all transactions between the operator and the system to help us identify those areas where practice and improvement are necessary.

Given this approach, this statement of the U.S. Maritime Transportation Research Board (1981) may be unduly pessimistic:

> The causes of maritime casualties are seldom technologically sophisticated and obscure. Almost without exception, the proximate or probable causes of collisions, rammings and groundings are well known and widely recognised as some form of human failing. Yet there is little recognition or understanding of the underlying causes of human error.

On the other hand, their statement is worth pondering that:

> There is an inverse relationship between the known causes of maritime accidents and the areas in which research is conducted. Most major maritime casualties are due to some form of human failing, whereas most maritime research resources are expended on hardware.

In conclusion, I have attempted, without being exhaustive, to outline a plan, and stress the need for a systematic approach to the design of man-machine systems. Such a plan does not guarantee zero probability of failure, but it, at the very least, reduces that probability: surely attainable meliorization is worth it. A camel may be a horse designed by a committee, but why not give the committee credit for having at least clearly defined its needs.

References

(1) Bainbridge, Lisanne. "Diagnostic Skil in Process Operation." Proceedings of the 1984 International Conference on Occupational Ergonomics, Vol. 2: Reviews, H.F.A.C., Toronto, 1984.

(2) Hunter, I.M.L. "The Solving of 3-Term Series Problems." *British Journal of Psychology*, 1957, 48: 286-298.

(3) Moray, N.P. (Ed.). *Mental Workload, I Theory and Measurement*. New York, Plenum Press, 1979.

(4) Senders, J.W. "Human Error and Human Reliability in Process Control." In Edgar, T.F. and D.E. Seborg (Ed.) Chemica Process Control 2, Proceedings of the Eng neering Foundation Conference. New York American Institute of Chemical Engineers, 1982.

(5) Sheridan, T.B., and Verplank, W. L. "Human and Computer Control of Underse Teleoperators." Man-Machine Systems Laboratory, M.I.T., Project NR 196-152. 1978.

(6) Wulfeck, J.W., and Zeitlin, L.R. "Human Capabilities and Limitations." In Gagne, R.M. (Ed.), *Psychological Principles in System Development*. New York, Holt, Rinehart and Winston, 1962.

(7) Maritime Transportation Research Board Commission on Sociotechnical Systems. "Research Needs to Reduce Maritim Collisions, Rammings and Groundings." National Academy Press, Washington, D.C., 1981.

[1]Source: Levels of Automation in Man-Computer D sion Making, for a single elemental decisive step, (a Sheridan and Verplank, 1978).

[EDITOR'S NOTE ON PAPER D]

Dr. Foley did not read his paper to Conference participants but instead enlarged on the principles and the elements of human engineering discussed in it. He provided specific examples of instances where a system design failed to recognize or take into account the requirements and capabilities of the system operator.

He referred to the North American car of the 1970s, the design of which did not permit easy operation by the average American male and female, even though it complied with the established and required standards. For example, the location of the foot pedals and the handbrake release lever, and the force required to operate the brake pedal all exceeded the physical capabilities of most American females. Similarly, the operation of the foot pedals and the degree of visibility afforded to the average American male operator also caused difficulties because little allowance had been made by designers for the physical dimensions of the majority of the potential operators. Dr. Foley also cited architectural design at one of the buildings at the University of Toronto as being inadequate for the purpose it was intended to fulfill. Drinking fountains at this particular building were designed specifically for use by handicapped people, but were, in actual fact, not accessible from a wheelchair. These fountains turned out to be equally difficult when used by the non-handicapped.

Dr. Foley also reviewed each of the three elements of human engineering: the human element, the machine element, and the information element, and emphasized that none of these should be considered independently of the others. The way an operator deals with information, the way information is presented to him, how he processes the information and controls or operates the system are all at the centre of the man-machine interface. He felt that the design of a system requiring human interaction is best accomplished by a committee, rather than by one individual, and that the expert in human factors should have input from the beginning of the design process when the specifications are being written. A sophisticated understanding of human factors is crucial to establishing the goal and requirements of a man-machine system; it is counter-productive to design a system without regard to human factors and then to select personnel to operate it. The design of a system must be conditional upon the capabilities which can be reasonably expected of the average human operator.

Dr. Foley gave two examples where design had proceeded without sufficient regard for human factors and where system goals had not been identified. One was a concrete mixer which was so awkward to load and unload that severe accidents during operation were a high probability. The other was a vehicle intended for use by the Canadian Armed Forces in the Arctic. The heavy and bulky protective Arctic clothing of operators made operation of the vehicles extremely difficult because the controls and the entry/exit hatch were all too small.

Another problem pointed out by Dr. Foley was that of determining what information is required to operate a system and how that information is best presented to the operator. The display of information should not be confusing, should not contravene population stereotypes, and should be instantly readable with a minimum of error in interpretation, regardless of the degree of stress being experienced by the operator in either a normal or emergency situation. Changes made in the design of an information display which are intended to be improvements should not be incremental and should be based on a re-assessment of original information requirements.

The need for engineering continuity was another element of the design process which was illustrated by Dr. Foley with an example. The procedural steps for emergency ejection from a particular aircraft were listed on a plaque which was mounted on the canopy of the aircraft. Unfortunately, the first step in the procedure told the operator to jettison the canopy, thus leaving him without any further directions for ejection.

Dr. Foley indicated that his paper dealt with the fundamental principles of human factors engineering only, but that his examples helped emphasize the importance of integrating human factors engineering into the design process.

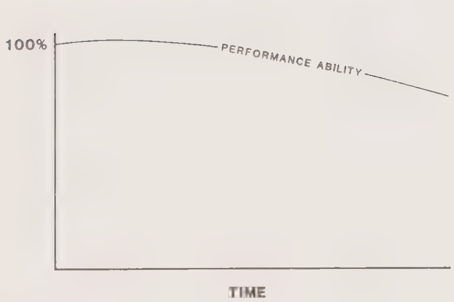


FIGURE 1

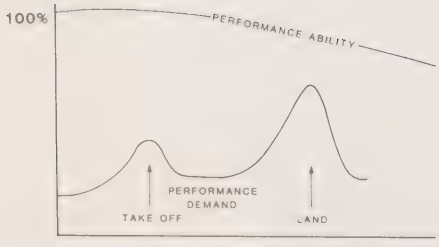


FIGURE 2

COMMENTARY ON PAPER D

Dr. H. Haakonson
Corporate Medical Director
Petro-Canada Resources

In responding to Dr. Foley's paper the only thing I can say is "Amen". I think that his coming from a position of academia, if you will, is absolutely vital. To think of designing a machine in 1984 without including human factors would, in my opinion, be gross negligence and to think of including human factors without doing so from the principles of an academic base would also be gross negligence. His paper has a great deal of relevance to the kinds of practical things that I and our other discussant will say. Dr. Foley has talked about the first step in a whole sequence of things that we try to do, or perhaps we should try to do, to reduce risk and in doing so, to increase the operator reliability in performing critical tasks.

I would like to deal with three specific issues from medicine, my area of expertise. The first issue is unexpected behaviour, or why do people not do what we expect they should do in the circumstances dictated? The second issue deals with the stress associated with significant events or incidents and the third is about leadership.

UNEXPECTED BEHAVIOUR

In discussing unexpected behaviour, for illustration, let us consider a crane operator, because I know there are some on offshore rigs. Let us suppose that a crane was so designed that when the operator wants the crane to lower, he lifts his lever up. That action goes against the stereotype which Dr. Foley talked about. Logic would tell us that eventually the operator is going to do it wrong because his mental processes, his stereotype, is going to tell him that for the thing to go down, he should push down. When is he going to do it wrong? Probably when you least want him to do it wrong, when the heat is on. So, it is fundamental that, in the design of whatever we are talking about, we factor out that human element.

Once we have done that, the next step is proper and adequate training of the individual to be capable of doing whatever is required of him and to carry out that action under whatever circumstances may prevail. But we cannot stop there. The training has to be followed by exercising, followed by training, followed by exercising, ad infinitum. There is no point in just training to a task if you do not exercise to see what is going to happen when the real situation arrives.

STRESS

Then we must not forget those things that we, in lay language, tend to call stress. At one point in his paper, Dr. Foley makes the point that "... mental work load may be the primary factor in operator error ..." and nowhere is that better demonstrated today than in the current generation of aircraft fighters where we really have reached the border of absolute overload for mental workload. That is not the only place.

In order to illustrate, refer to the plot of performance against time (Figure 1) and consider a hypothetical situation. Let us say that for each of us we have a performance ability which starts off at some 100% value and over time, whether that be the duration of a day as we become fatigued, or the duration of a lifetime as our body becomes less and less capable, the performance ability drops off.

Let us compare that against the performance demand which exists in a given situation. Dr. Foley provided an appropriate illustration of the commercial aircraft pilot fo whom the performance demand increase upon landing was reflected in his heart rate increase. In his case, the performance graph would have looked something like that ir Figure 2. The difference between performance ability and performance demand is referred to as coping capacity: the ability which is in excess of what is required. It is a capacity to deal with things over and above that which you may be facing at the ver moment.

Let us now factor in some other demands stress, if you will. Let us suppose ar individual is on his second or third day bacl on the rig after his three weeks off, and he i a little hung over, because we have a per ception of what people tend to do whe they are on their time off. So, one woul have to guess that, whatever ability h might have had under other circumstances that ability is somewhat decreased unde this situation. Let us suppose that there i some marital strife going on, and further, le us suppose that he is quite physically unfi All very real possibilities in an individual sit uation and all to some degree decreasin his performance ability (Figure 3).

I had a professor of obstetrics who used t describe his profession as being one of lon periods of boredom interspersed with sho periods of absolute terror. When a com plication of delivery occurs, it is a momer of absolute terror. You have only very sho moments to make very critical decisions an get them right. That, I think, describes som of the critical tasks in the offshore industr where a very long boring job of surveillanc may be interspersed with a critical tas related to an emergency, and so th

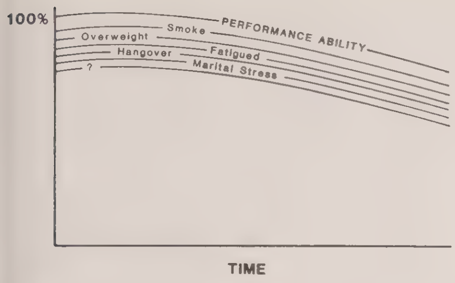


FIGURE 3

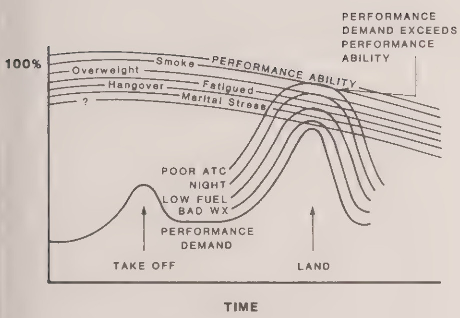


FIGURE 4

demand goes up appreciably at that particular moment. You can pick whatever emergency you like. Have it happen at night and you have just increased the demand a little bit further. Have it happen when the sea state is as it was when the *Ocean Ranger* went down, and you have really pushed the demand right out of proportion. Indeed, you run the risk of having the demand exceed the ability. I propose that a good number of critical tasks occur in circumstances where the performance demand exceeds the expected performance ability (Figure 4). The difference between having an accident under this situation, and only having an incident, is a result of training, experience and, I suppose we should add, good luck.

In order that the operator performance ability be maximized, we must ensure that the operator is fit medically, physically, emotionally, and spiritually. There is a critical place here for the operator to be fit through his own assessment, not just external assessments such as a medical person might provide. When we talk about significant events, we have to be very clear as to the difference between an incident and an accident. If the difference between the two is based on experience and training and luck, then we have to pay attention to those factors of the three that we can control. We can improve upon our situation by paying attention to the incidents and preventing them from becoming accidents and that is the pitch I wanted to make at this point.

I would like to conjecture for a minute – what do you suppose would have happened if the *Ocean Ranger* had not gone down? I do not think there is any doubt that there have been a number of advances and much progress made in offshore safety because the *Ocean Ranger* went down. What if it had not gone down? None of this attention, nor a whole lot of other attention, would have been focussed. Most likely the people who were aboard the drill rig throughout that period of terror would have come away from it saying, "That was a close call." Maybe they would not have even recognized quite that much.

It is only through paying attention to the ongoing close calls that action can be taken to prevent disasters. Why wait for the crane operator to drop a pallet on somebody because he moved his lever the wrong way? Why not have a system that regards every occasion when the crane operator goes to move the lever the wrong way as an incident, so that it is brought to attention of supervision. After it has been brought to attention enough times, it is going to click, "Hey, there is something wrong with the way that system operates."

LEADERSHIP

Leadership is critically important in the whole business. There is no point in our telling people what to do if we do not show them by way of our own example. I would remind you in closing that the single greatest risk to safety is human performance. There is a closing sentence in Dr. Foley's paper that says, "Most maritime casualties are due to some form of human failure whereas most maritime research resources are expended on hardware." Ladies and gentlemen, I think it is time to strike a balance.

COMMENTARY ON PAPER D

H.L. Zinkgraf
Vice-President
SEDCO, Inc.

First let me say that "operator competence" is a subjective statement that requires definition: what is the level of competence required? On what system operation? Under what condition? A man's capability and competence to control a machine or systems are dependent on so many factors, including, but not limited to:

1. Basic skills, education, and most important, common sense;
2. Training, on the same or similar machine/system;
3. Experience;
4. Information and operational data presented to him;
5. The physical control elements required for correct operation of the machine/system.

We must assume that the physical functions required to successfully control the machine or system are within the capability of the operator and that no unusual physical attributes are required. It also must be assumed that the machine or system has been designed correctly and is fully capable of proper operation. A man, as viewed by an engineer, is a complete servo-system. He comes complete with a computer (brain) that can rationalize (i.e., store data, reach conclusions, issue commands) and execute with arms, legs, hands, feet, and fingers. He receives "feedback" from sight, sound, touch, smell, and sometimes taste. He is equipped with the same capacity as a P.I.D. controller; he can and does function as a three mode control system.

As an example, let us consider a man driving a car. His computer is receiving information continuously from eyes, ears, and touch. He is steering the car, travelling in the correct direction, along the correct path, at a reasonably accepted speed, and all the while carrying on a conversation with the girl alongside him. He is constantly compensating for ever-changing variables on a micro second basis and is not even conscious that he is doing so. He is using all of the computation capability, sensor inputs and servo-mechanisms, as a "closed loop" control system. Now comes the most important capability. A child rides his bicycle out into the street. His sensors (eyes) provide an interrupt or alarm message to his computer (brain). It instantly analyzes the alarms, decides what action is required to prevent hitting the child, issues the command (in this case let us assume it is to put on the brakes), sends the command to the leg, applies what brake pressure it has calculated, integrates the response by sight and feel, and compensates for the action by more or less pressure. He perhaps sees the action is useless and reverts to a swerving of the path of the car using a new group of devices (arms and hands) and the process again repeats itself. What a wonderful machine, as long as the sensors are in working order, the computer is functional, and the servo-mechanisms respond to commands. It can work, it can compute, it can respond, as long as the machine has been programmed correctly. In this case the program is extremely simple – Do Not Run Over The Child.

With this kind of machine to start with, let us now examine how we utilize it in the real world that is the subject of this Conference: operational safety of an offshore drilling unit. A modern mobile offshore drilling unit is a complicated machine, composed of a large number of other machines and complex systems. If the designer, owner, and operator have done their job, there are no unimportant machines or systems onboard. The entire system was designed and equipped to perform only one function: to safely and efficiently explore for hydrocarbons by drilling a hole in the ground under hundreds or even thousands of feet of water. There is not enough time to adequately cover even a small percentage of the systems that require the man/machine interface so I will concentrate on one of those that is critical in the context of this Conference, the ballast control system.

The man/machine interface in this system is focussed at a control console. These consoles may take on many configurations and can be as simple or complex as the designer chooses. The control functions to be accommodated are the opening and closing of valves and the starting and stopping of pumps. The display of liquid levels, the draft at corner columns, the inclination of the vessel in both axes, and the status of valves and pumps are the minimum "feedback" or information required.

Now that does not seem to be all that complicated, but it is. The first simple consideration is to present the information and control elements in a logical and understandable way.

1. The control panel layout should be graphical; the graphic displays of tanks, valves, pumps, and piping should be aligned with the orientation of the vessel, that is the bow of the display should be oriented with the bow of the vessel, portside to port, etc.
2. The valves, tanks and pumps should have identities that make them unique.
3. The indicators for valves should be unambiguous: "Open" one color, "Closed"

another. There should be some indication that the valves are moving by using, for example, blinking lamps, or a moving dial. Such displays should also indicate the direction of movement.

4. The pump control should have the same logical presentation of condition (running or stopped) with an indication of operating dynamics (motorload, flow).

5. The liquid levels should be presented in a continuous method in either measured height or in tons and with the ability to assess the rate of change and the direction of change.

6. The draft should be displayed in a continuous manner with enough damping (or averaging) such that action of waves does not make readings useless.

7. The display of the inclination of a vessel should be presented in a straight forward non-ambigious manner oriented in the correct vessel coordinates.

The above comprises the absolute minimum of control indicators required. The more straight forward and simple these are, the better. When man is operating the machine he should become part of the system. He should instinctively look for an indicator in the proper orientation of the vessel, he should be sensitive to the rate of change of the vessel attitude by knowledge of the rate of flow or change in the fluid height or weight of the tanks. This can only be successfully accomplished when:

1. The operator has been properly trained and has experience in the operation of the equipment. The training must include fundamentals in the stability theory for the vessel he is attempting to control.

2. There must be a ballast procedure plan designed for the particular vessel, that is, designed to safely control the heel and trim of the vessel with only minor corrections being made to accommodate variables in vessel loading. This applies to ballasting up or down. Concise and unambiguous instructions should be in place.

3. The operator should be trained and drilled to perform the functions required to accomplish the plan, almost without consciously being aware of it.

4. Alarms for out-of-trim condition beyond a fixed limit should be presented to the operator both visually and audibly.

The designer must be careful to present the operator with those items of information that are obligatory to safely perform the ballasting function. He must not clutter the control panel with unimportant indicators or controls which would only tend to confuse the operator. We have found it extremely useful for the ballast operator to be trained on a computer, programmed to calculate his stability margin, heel and trim with any condition of vessel loading, and with the ability to damage any compartment, voids or tanks. This teaching aid allows the operator to plan in advance actions to be taken under emergency conditions. We have implemented these systems on-line where the tank loads are continuously input to the computer and the stability is calculated once per second. We have also implemented these off-line where all information is manually input. I mention this type installation not in the light of being necessary but as being useful from an operational and training standpoint. It does not relieve the requirement for the operator to manually perform his stability calculation.

I would like to conclude with this comment: a man, properly trained and provided the correct tools, can perform complex functions with competence. He is indispensable and also irreplacable.

Summary of General Discussion Following Paper D

Mr. G.L. Hargreaves (Consultant, U.K.) cited alleged practices during World War I with regard to training: that complex tasks were broken into a series of simple tasks so that very little training was required to perform them. They resulted in operator boredom and a high accident frequency. He indicated that research in Sweden has shown that it is probably preferable to train operators to a more competent level which allows them to exercise discretion and initiative and results in more efficient performance.

Dr. P. Foley (University of Toronto, Dept. of Industrial Engineering) agreed that training, as an integral part of any system, aims to achieve greater reliability of the system by reducing operator error. One approach is to provide the operator with an internal model or understanding of the systems that he is to operate and to train him to control activities which deviate from that model. Another approach is to teach the operator a set of operating rules, without imparting to him a knowledge of the entire system. Dr. Foley believed that a synthesis of these training approaches would be most effective, and that all training should include an element of internal modelling which, in combination with an optimum information display, will allow the average person to perform the task. Operator errors may also be reduced by the selection process for personnel, as qualifications are an indication of a person's potential and existing internal modelling. Those errors resulting from the machine's design inadequacies, such as failure to accommodate population stereotypes, must be rectified through design modifications.

Dr. A.E. Collin (Energy, Mines & Resources Canada) pointed to three differences between land and offshore drilling which must be considered in the management and training of persons to work on an offshore drilling rig: 1) a worker must become accustomed to the constant motion of the rig while work is being performed; 2) the external environment in the offshore does not afford the worker the same psychological support experienced in land-based operations; and 3) the MODU must provide adequate defence against a potentially hostile environment. Designers must be cautious in viewing an offshore rig as an island and must carefully consider the situations where the rig is not a self sufficient island and must defend itself against an unforgiving environment which does not offer the same dimension of escape available on land.

Mr. H.L. Zinkgraf (SEDCO, Inc.) verified that these considerations are not new to industry and that all available resources are being applied to make drilling offshore more efficient and safer for the worker.

Dr. O.M. Solandt pointed out that it is important to consider the limits of human capabilities in the design of equipment and that an operator should not be deluged with complex or irrelevant data which does not add to his operation of a system. In summary Dr. Solandt indicated that, although the Conference had dealt with the level of human factors involving an operator and a subsystem on a rig, it is important to consider yet another level of man/machine interface: that of an entire crew operating as part of the complex system of the rig as a single entity.

Ir. R. McGrath
'ice-President, Drilling
etro-Canada

Ir. McGrath has a B.Sc. in Mechanical ngineering and worked with Mobil Oil ;anada from 1966 to 1977 in various engi- eering positions. From 1977 to 1980 he ined Gulf Oil as co-ordinator for Offshore rilling and as Manager of the Drilling Divi- ion. Since 1980 he has been with Petro- ;anada where he is currently Vice-Presi- ent, Drilling, and responsible for Petro- ;anada's land and offshore drilling activi- es, including the company's Atlantic 'egion.

PAPER E

Organization and Management

ABSTRACT

This paper addresses the effectiveness of management and human organization for eastern Canada offshore operations during both normal operations and unplanned events. The paper develops a perspective of the organizational and command structures and communication methods in place for exploration programs offshore in relationship to the historic aspects of offshore drilling, the sinking of the *Ocean Ranger*, the environment, and the nature of marine and drilling operations. This paper discusses recent Government and industry initiatives which attempt to make the offshore a safer work place, organizational and command structures, and the elements of emergency response. Conclusions are presented based on current practice. It is a conclusion of the paper that existing management organizations are generally effective. Several outstanding issues are presented which are relevant to the topic and, we believe, need to be addressed by industry and Government for enhanced safety offshore.

BACKGROUND

The sinking of the *Ocean Ranger* was an unfortunate incident that, based on rig design and industry experience, should never have happened. However, it did happen and, as a result, this Commission, the industry, and government are focusing their resources and attention on determining what caused the incident and, secondly, are contemplating and, in some cases, implementing new guidelines, standards, and procedures in an effort to make the offshore safer for all drilling units, support systems, and personnel who derive their livelihood from the oil and gas industry offshore Canada.

Exploration for oil and gas offshore goes back to the early 1900's and, since that time, some 45,000 offshore wells have been drilled worldwide. As the demand for oil increased, exploration activities moved into deeper waters and more severe environmental areas. Technology has had to advance at a rapid pace to meet the challenge. Offshore drilling has progressed from using a conventional land drilling rig mounted on a wooden platform over the water to submerged barge-mounted drilling units, submersible drilling units, jackups, anchored floating barges, anchored drillships, anchored semi-submersibles, dynamically positioned drillships and, finally, dynamically positioned semi-submersibles. Each advancement required the development of innovative procedures, equipment, tools, and improved training and skills for crews to ensure safe and efficient drilling operations in the new frontier areas.

Progress has not been without incident. Between the years 1955 and 1981, a total of 140 mobile unit mishaps were recorded, 47 of which resulted in a mobile drilling unit being lost at sea or taken out of service.

Offshore operations on Canada's East Coast commenced in 1966 on the Grand Banks with the anchored drillship *Glomar Sirte*. Since that time, approximately 200 wells have been drilled offshore Canada's East Coast from the Scotian Shelf to Davis Strait. Drilling units operating on the East Coast of Canada have included 15 drillships, 7 jackups, and 16 semi-submersibles. The drilling units were selected based on water depth, environmental considerations, the well program, timing, and, in some instances, availability. Recently, there have been two incidents of significance which marred industry's safety and performance record on the East Coast of Canada, the sinking of the *Ocean Ranger* and the Uniacke well blowout. These events put the industry and Government on notice that mishaps could also become part of the Canadian experience.

This does not mean to imply that prior to either of these two incidents Government did not require offshore operators to prove the existence of an adequate management system or that the operators did not meet and, in most cases, exceed regulatory requirements. Quite the opposite, we believe the industry has been acutely aware of the necessity for advancing the management systems consistent with the technological marine and drilling advancements. The successful response to the Uniacke well blowout may, in part, be due to the recent attention paid to emergency response planning as a direct result of the *Ocean Ranger* incident, primarily in the co-ordination of operator, contractor, support services, and regulatory plans and resources that has taken place since February 1982.

However, even with these co-ordinated plans in place, there are still factors such as equipment limitation and the marine environment which affect our ability to respond to an offshore situation. Considering the marine component of offshore drilling, it is well accepted that personnel and equipment experience an element of risk while operating offshore. As offshore operations moved to more severe environments, increased attention was paid to the support and

backup systems necessary for safe and efficient operations. Current examples are training and prevention programs targeted at specific activities for all offshore crews, design and selection of equipment consistent with the working environment, state-of-the-art survival equipment and emergency appliances, and the implementation of satellite communications technology. The extensive level of support provided to the offshore drilling activity is unparalleled when compared with conventional marine activities such as shipping and fishing.

DESCRIPTION OF THE ENVIRONMENT

The physical environment offshore the East Coast of Canada is as varied and severe as any experienced in the offshore exploration and development areas of the world. The Labrador Sea and Davis Strait areas are confined to drilling operations during the open water season from July to November. Sea ice constrains these operations at the beginning of the season, and severe autumn storms end the season. The presence of iceberg activity requires constant surveillance and management if operations are to continue in a safe and efficient manner. Ice conditions, deep water, weather, and the relatively short operating season make dynamically positioned vessels the preferred drilling unit for this area as they are able to systematically move away from encroaching sea ice or icebergs and to quickly re-establish connection with the well once the hazard has passed.

On the Grand Banks, icebergs and sea ice are also significant factors, and the presence or absence of them varies from year to year. Extreme environment, heavy weather semi-submersibles have been utilized on the Grand Banks because of their better motion characteristics for year round operations. Even these semi-submersibles are not designed to work in sea ice and, as a result, temporary suspension of drilling activity is planned for and implemented when sea ice encroaches on a drilling location. This was evident in February and March of 1983 when sea ice covered portions of the exploration areas on the Grand Banks. Sea ice also limits the drilling season in the Gulf of St. Lawrence. Sea ice occurrence is rare on the Scotian Shelf but winter storms require the utilization of severe environment semi-submersibles in water depths greater than 60m and large, new generation, heavy weather jackups in shallower water depths.

Other environmental factors which are present and must be considered and addressed in the operations plans for safe operations include: cold air and sea temperatures which necessitate winterization and protection of machinery and work areas; covered lifeboats, fast rescue craft and availability of insulated survival suits for crews both in transit by helicopter and in the event of ship abandonment; fog which reduces visibility and challenges logistic management for the efficient movement of crews; and icing on supply vessel and drilling unit superstructures which necessitates reduction of available variable deck loads to compensate for the calculated ice buildup. Helicopters are not permitted to fly when there is a risk of icing. Ocean currents, although less significant, are important and must be considered in the mooring analysis for semi-submersibles and overturning moment analysis and foundation support or scouring effects for jackups. Tides to date have not posed a constraint on operations except at the mouth of the Hudson Strait where the tides and resulting water motions require that the operational procedures consider the currents associated with the tide.

RESPONSE PLANNING INITIATIVES

Since commencement of offshore operations in 1966, the operating companies, drilling contractors, and Government have continually strived to make the offshore a safer work place. Emergency response plans, and operational procedures and guidelines were developed and formalized so that an unplanned event could be dealt with in an expeditious manner. However, these plans, procedures, and guidelines are only as good as the equipment, experience, and training of personnel, the communications system, and the organization and command structure. The loss of the crew of the *Ocean Ranger* demonstrated some weaknesses existed in the system. Since the sinking of the *Ocean Ranger*, emergency response planning activity has been intensified and new initiatives have been undertaken, in consultation with Government, in order to enhance safety for offshore workers. Some of these improvements include:

1. Multi Operator Agreements. In the areas where more than one operator is active, agreements are entered into amongst the operators to improve safety offshore through co-ordinated communication and logistic support. For the Grand Banks operators these include:

- Flight/Marine Monitoring Service Plan
- Grand Banks Operators' Alert/Emergency Co-ordinated Response Agreement
- Grand Banks Operators' Emergency Resource Sharing Agreement
- Support Craft Services Sub-charter and Assignment Agreement
- Grand Banks Operators' Joint Ice Detection and Ice Reporting Plan
- East Coast Operators' Management Committee

2. Emergency Response Plan. Individuals who assume specific emergency response duties are usually selected based on their job function and experience. The Emerger cy Response Plan serves as a checklist fo these individuals but primarily benefits oth personnel who may have to assist or repla the designated individual in a given emergency response situation. The Emergency Response Plan provides direction for the mobilization of personnel and equipment t any serious emergency that may occur. Through the auspices of the Canadian Ea coast Offshore Safety Committee (CEOS(an industry common emergency response manual was prepared for use by operator as a format for company specific plans. T emergency situations addressed by the p are:

- Code 1 – Personnel Injury or Death (only)
- Code 2 – Loss of Well Control
- Code 3 – Rig Damaged or Threat of Rig Damage
- Code 4 – Overdue or Lost Aircraft
- Code 5 – Lost or In Distress Vessel
- Code 6 – Divers
- Code 7 – Oil Spill

For rapid response, it is important that the essential details of an emergency be communicated immediately to the persor responsible for dealing with the emergen Proper training, experience, and skill of o site personnel is essential. Frequent communication exercises help to assess the readiness and ability of on-site and shore based personnel to respond effectively tc emergency situation.

3. Alert Response Plans. Alert Response Plans were developed and implemented responding to certain extraordinary situations which may not require immediate action but could lead to a serious incider The Alert Response Plan is co-ordinated with the other offshore operators workin the immediate area to ensure that all ava able resources are used in the most effic manner.

4. Alert/Emergency Response Manuals. The recent development of combined Alert/Emergency Response Manuals wa logical progression which recognized tha one volume could cover both response aspects, some responses had no Alert phase and, in many cases, the Alert and Emergency Responses were identical, ar the response organizations for Alert and Emergency situations were likely to be ic tical.

5. Ice and Iceberg Management Plan. Ic management plans have been develope and implemented for operations in ice fr

quented waters. The plan provides guidelines for early detection and response to the threat of ice. If the ice threat cannot be managed then avoidance is recommended. The Grand Banks Operators' Joint Ice Detection and Ice Reporting System provides a co-ordinated information gathering system by which all ice observations are compiled and joint discussions reached on ice management matters.

6. Heavy Weather Policy. Heavy weather policies have been implemented to ensure that proper measures will be taken to suspend operations in an orderly and safe manner in the event of forecasted bad weather. In order to protect personnel and prevent damage to the equipment, a series of precautionary actions can be initiated depending on the severity of the environmental conditions. The precautionary decisions are categorized as follows:

- suspend rig operations and hang off the drill string
- disconnect from the well
- deballast to survival draft
- pull anchors and move off location
- evacuate the drilling vessel

7. Flight and Marine Monitoring. All flights dispatched from the shore base and drilling unit are monitored by the Central Flight Following Facility. The contractor provides monitoring of routine and emergency helicopter operations and also maintains and updates supply vessel status and location. The advantage of a central monitoring facility in an emergency is the ability to immediately determine which aircraft or vessel is in the best position to respond and render assistance.

ORGANIZATION AND MANAGEMENT

We believe that the present organizational structures for offshore operations are effective in ensuring safety of personnel and equipment for normal and emergency situations. The operators, contractors, and regulatory agencies on the East Coast have established safety as a priority and operational efficiency as a secondary consideration. It is the experience of industry that safe operations result in efficient operations. The operators working on Canada's East Coast vary in experience and operations knowledge. The drilling contractor who is new to the area and working for an inexperienced operator is at a disadvantage in his ability to relate to the local conditions and regulatory requirements. This operator/contractor combination relies heavily on other experienced operators and contractors to share their knowledge. It is through this co-operative sharing of knowledge and experience that potentially catastrophic situations are averted and the learning curve is accelerated.

NORMAL OPERATIONS ORGANIZATION

For normal drilling operations, the organization structure is made up of two distinct components: the operators' organization and the prime contractors' organization and onboard command structure. The oil company or operator generally acts as the focal point of the exploration program. The operator:

1. Defines the exploration program;
2. Contracts the drilling unit, helicopter, and marine and support services for a specific program;
3. Communicates directly with regulatory agencies on all matters relating to the program. The regulatory agencies deal directly with the operator in granting program approvals;
4. Sets up and maintains a shore support base facility for materials, supplies, administrative and technical support to operations;
5. Develops and implements emergency response plans and is responsible for ensuring compliance with all safety rules and regulations.

The operator's management structure for offshore operations includes:

1. Senior management at the operator's head office who interface with the client group and partners on timing, schedules, and budgets of ongoing and future exploration activities.
2. Operations management is normally located in the immediate vicinity of the drilling activity such as St. John's or Halifax. The operations office monitors day-to-day drilling activities, provides the logistic support and base personnel to ensure the equipment, services, and supplies necessary for executing the drilling program are available in a timely and cost effective manner. The operations office also consults on a daily basis with the operator's senior representative onboard the drilling unit to ensure his requirements are met and that the drilling operations are progressing as planned, informs the regulatory bodies of progress, current and planned activities, liaises with the drilling contractor and service support contractors on requirements and needs, ensures that the communication system is functional and operating at all times, consults with other operators on possible requirements and sharing of resources, and liaises with senior management as necessary.
3. Onboard supervision is performed by the operator's senior representative who is responsible for ensuring that the drilling program is followed and that the drilling objectives are met with due consideration for safety, efficiency, and protection of the environment. The operator's senior representative informs the drilling contractor's representative onboard of the operator's requirements.

The drilling contractor's organization consists of:

1. Senior management at the drilling contractor's head office who negotiate the drilling contract and establish policies and procedures for the conduct of operations;
2. Shore based management and support staff located near the operator's base onshore. The function of this staff is to monitor performance and progress of the drilling unit, purchase and expedite supplies and materials for the maintenance of contractors' equipment, ensure that adequately trained and experienced crews are available for crew rotation, consult with the operator on planned and current activities, and liaise with other contractors in the area. Shore based management is responsible to the operator and the drilling contractor's senior management for safe and efficient operations in accordance with applicable regulations and guidelines, and consistent with good oil field practice;
3. The marine crew and drilling crew. Internationally, the organizational structure defining the onboard command hierarchy varies with the type of drilling unit, its flag, the contractor and the operator. These organizations have developed over a number of years of experience and successful operation and are difficult and, in most cases, impractical to mix or alter. In Canadian waters, the preferred approach has been to a common command structure with one individual being identified as being responsible for the safety and security of the vessel and crew.

Information flow to the drilling unit for the benefit of the operator and contractor includes:

- Environmental, ice, and seastate
- Desired deviations from the approved well plan
- Aircraft, helicopter and marine vessel status
- Resupply schedule and status

Information flow from the drilling unit includes but is not restricted to:

- Weather and ice information for input into forecasts
- Daily drilling status report and progress
- Planned activities
- Equipment status
- Supply status

The communications system employs state-of-the-art technology with adequate redundant components to ensure totally reliable communication.

There are three basic types of drilling unit employed offshore the East Coast of Canada and, because of varying operational requirements, the onboard command structures of each are discussed separately. The role of the operator's representative onboard is the same for all situations discussed below and ensures that the regulatory obligations and operator policies are met and/or considered in the decision making process.

Jackups

The jackup rig is considered a marine vessel while under tow and is under the charge of a barge master or rig mover during such operations. Once the jackup is on location and stationary, there is a formal signover procedure which transfers responsibility from the rig mover to a senior drilling representative of the contractor. The senior drilling representative is then in charge and is responsible for the execution of drilling operations and safety of crew and equipment. Responsibility is again formally transferred to the rig mover when drilling operations are completed and the jackup is ready to be moved.

Drillships

A drillship is subject to the *Canada Shipping Act* and requires a master with Unlimited Foreign Going papers to be onboard. There are two types of drillship, the dynamically positioned drillship and the anchored drillship. The dynamically positioned drillship maintains position over the well by thrusters. This requires marine skills to be employed at all times and, as a result, the captain is in overall command. On an anchored drillship, however, the captain is normally in command when the ship is in motion. While anchored on location, the captain is responsible for the safety of ship and crew and stationkeeping, and the rig superintendent is responsible for the drilling operation and control of the well. In the event of an emergency, the captain takes full command.

Semi-submersibles

Self-propelled, semi-submersible drilling units are classified as marine vessels and, as such, are required to have a captain or master mariner onboard when the unit is functioning as a vessel. However, twin hulled, column-stabilized structures such as semi-submersibles do not behave like conventional ships and have complex ballasting systems to maintain stability. In our opinion, industry recognizes that both marine and drilling skills are required to effectively command a semi-submersible drilling unit.

There are two basic command structures for semi-submersible drilling units, the European model and the American model. The European model follows the conventional marine command structure with a captain in charge. Normally, the captain is required to hold Unlimited Foreign Going Masters' papers and will have served as a subordinate officer on a semi-submersible for two or more years prior to taking command. There are two variations to this model.

1. The captain is in complete command of drilling and marine activities.
2. The captain is in charge of the marine crew and the senior driller is responsible for rig operations under normal conditions. Total command reverts to the captain when there is a threat to vessel or crew.

The American model has the senior onboard contractor's representative in charge at all times. This person is fully knowledgeable on drilling operations, has been trained in marine operations, and is required to be in possession of a column-stabilized (MODU) masters' ticket. Although the senior onboard representative is in charge, the captain remains responsible for the safety training of crews and is delegated command of the unit when in transit.

From the operator's point of view, we endorse the philosophy that one person should be clearly in command at all times. The onboard person in command must have management and organizational experience, a sound understanding of drilling and well control procedures, knowledge of the working limitations of the drilling unit and complexity of support logistics, and be totally familiar with the marine environment. If a captain is in command, he must have a good perception of drilling operations and must have worked in a subordinate role on a MODU prior to taking command. If the contractor's senior onboard representative is in command, he must have full knowledge of semi-submersibles and must be in possession of a MODU masters' licence.

EMERGENCY RESPONSE ORGANIZATION

Safety in an emergency situation is of prime concern and a clear understanding of who is in command is essential if emergency situations are to be dealt with in an organized, efficient manner. In an emergency, the responsibilities and actions necessary are clearly defined in the alert and emergency response planning materials. The emergency response organization varies from operator to operator but is usually very similar to the normal response organization for that operator. The basic difference between normal and emergency responsibilities is that, in an emergency situation, shore based management performs a central co-ordinating role and the onboard personnel may have to make extraordinary decisions.

During emergency situations, it is essential that communications be as direct as possible. The drilling unit communicates with the operator and directly with dispatched support on operational issues. An Emergency Command Centre is established in the operator's office, and the contractor's shore based representative is requested to proceed to the emergency command centre. All communications (direct or monitored) are passed to the Emergency Command Centre. This permits timely and knowledgeable decision making and prevents unnecessary third party communications with the drilling unit. The Emergency Command Centre will co-ordinate all other elements in the response structure which can supply assistance. All operators recognize the importance of the communication process in ensuring an effective emergency response.

The basic elements of existing emergency response organizations are:

1. An organizational and command structure should identify lines of communication and actions to be taken by key emergency response personnel.
2. Emphasis should be on experience and training. In an emergency, the crew must believe in the competency of the person in command to avoid delays in response.
3. Emergency response exercises and drills under controlled conditions should assist in assessing the effectiveness of the plan, readiness of response organization, and maintenance of a high profile on safety and prevention programs. The exercises and drills must be co-ordinated to include the drilling unit, supply vessels, helicopters, shore base support staff, Coast Guard, Search and Rescue, and regulatory agencies, and designed to test the weaknesses and strengths of the communications system and logistic support network.
4. Operators' Liaison Committee (OLC) and related joint management and response assistance plans, such as those between the Grand Banks Operators, formalize a mechanism of extra operator assistance.
5. Effective lines of communication should be as short and direct as possible.
6. The individual responsible for directing onboard emergency response operations must be prepared to make extraordinary decisions in lieu of normal consultative processes.

CONCLUSIONS

From this paper, which addresses the organizational and management structures now in place for the conduct of safe and efficient operations offshore, the following conclusions are drawn.

1. The oil industry has operated offshore for approximately 80 years and has 18 years of experience offshore the East Coast of Canada. Technology has advanced at a rapid pace to meet the demands of drilling in remote locations and severe environments. This progress has taken place with due consideration for safety of personnel and equipment, efficiency of operations, and protection of the environment.

2. The sinking of the *Ocean Ranger* demonstrated to industry and Government that serious mishaps can occur in the Canadian offshore. Since this incident, Government and industry have instigated new initiatives relating to safety, training, and emergency reponse planning. The immediate and successful response to the Uniacke blowout may have been, in part, attributed to these recent initiatives.

3. It is recognized that there is a significant marine component to offshore drilling operations. However, the level of support provided to offshore drilling is now extensive and unparalleled in the marine industry.

4. Our industry and Government have established human safety as the priority, and operational efficiency as a secondary consideration. It is the experience of industry that safe operations result in efficient operations.

5. There are two distinct elements within the organizational structure for current drilling programs, the operator and the drilling contractor. While they have slightly different perspectives, each has to be cognizant of the other's concerns and needs, and they must work together towards a common objective.

6. The onboard organizational and command structure for normal operations is, for the most part, identical to that for an emergency situation.

7. The onboard person in command must have management and organizational experience, a sound understanding of drilling and well control procedures, knowledge of the working limitations of the drilling unit and complexity of support logistics, and be totally familiar with the marine environment.

8. Safe, efficient, and successful normal and emergency operations will be fostered by properly trained, experienced, and skilled personnel who have confidence in the person in command.

9. Continuous dialogue between the drilling unit and the shore base is essential. In order to accomplish this, state-of-the-art communications systems with necessary redundant components have been integrated into offshore drilling operations.

10. The establishment of an emergency communications centre at the operator's base minimizes the generation of misinformation in an emergency and ensures the availability of a complete record of all communications with the drilling unit.

11. There is a calculated risk to all ventures which must be understood and accepted. Government and industry are committed to continuing to investigate means of minimizing and, where possible and practical, reducing these risks.

ISSUES FOR DISCUSSION

This paper concludes that existing organization and management structures and communication methods are effective in dealing with both normal and emergency situations offshore the East Coast of Canada. The outstanding issues, in our opinion, are:

1. In Canada, there are no formalized qualification requirements for key positions onboard the drilling unit. Standards of required knowledge, experience, and competence levels for key positions have to be clearly defined and developed by both industry and Government, and a Canadian certification program which is compatible with other similar international certification programs must be implemented.

2. The ratio of trainees to experienced personnel onboard offshore drilling units must be reviewed by industry and Government, and an upper limit established in the interest of safety. The industry has expanded rapidly over the past twenty years and technology continues to evolve. In our opinion, industry faces a situation, particularly in Canada, where there is a shortage of adequately trained, experienced, and skilled individuals to effectively fill the key positions on drilling units. Contractors must recruit from the world market for qualified personnel to fill key positions while, at the same time, provide training opportunities for Canadians.

3. Canadianization of offshore crews must progress at a controlled pace and not accelerate to the point where safety will be compromised.

4. We believe that marine and drilling regulations, as they relate to offshore safety and drilling, are not industry specific. To ensure that these regulations become industry specific, joint involvement between industry and Government, with due consideration to the views and experience of operators, drilling contractors, and service organizations, is necessary.

5. The roles and responsibilities of industry and government agencies with respect to emergency situations need to be clearly defined.

6. The industry and Government need to come to an understanding regarding the level of search and rescue support required to support offshore exploration, development, and production activities.

7. There has to be a mutual understanding and acceptance by industry and Government as to the effectiveness of lifesaving appliances prior to their implementation.

References

(1) "An Evaluation of Industry Safety Management in Eastern Canada Offshore Drilling Operations." Submitted to the Royal Commission on the *Ocean Ranger* Marine Disaster. Manadrill Drilling Management Inc., March 1984.

(2) "Risk Assessment." Ian Burton. March 1984.
Part I – A Perspective on Risk with Special Reference to Eastern Canada Offshore Exploratory Drilling.
Part II – A Preliminary Risk Assessment of Human Safety in Exploratory Drilling Operations for Oil and Gas In the Eastern Canada Offshore Area.

(3) "Royal Commission on the *Ocean Ranger* Marine Disaster – Assessment of the Normal and Emergency Command Structures Relating to Drilling Systems for Eastern Canada Offshore Drilling Operations." Currie, Coopers & Lybrand. May 25, 1984.

COMMENTARY ON PAPER E

J. Hielm
Senior Contingency Planner
Elf Aquitaine Norge A/S

I was asked to comment or to amplify on Mr. McGrath's paper. Apart from complimenting Mr. McGrath on his presentation I must confess that I do not really feel in a position to make any comments. This is because his paper, as well as being general in content, is obviously adapted to the Canadian situation and I am not familiar with the operators' arrangements and agreements, and therefore any comment that I make could be way off target and consequently misleading and wasting your time. So, I have decided to amplify on certain things, and what I will do is go through some of the basic elements of contingency planning and crisis management.

I would like to make some general comments. I will show you how the Norwegian operators have developed a model contingency plan and then, time permitting, I will show you what we have done within my own company regarding the onshore emergency organization and the personnel qualifications and the training program that we have established. What I am going to say may, to a great number of you, seem both obvious and evident. Nevertheless I am often amazed to see how many times the obvious and evident are neglected in an emergency situation, simply because one has not carried out the thought processes or the evaluation relating to the incident. When developing a contingency plan for various situations, it is impossible to cover all the circumstances that can be involved. If you try and do that, you do not have a contingency plan, you have a filing cabinet. As a consequence, one cannot finalize in detail what should be done, who should do it, or how it should be done. The plan must therefore be limited to general operational guidelines to which elements may be important for the further development of the situation. The final plan of action can first be determined when the emergency has arisen and all the known elements can be included in the situation evaluation. One might say that the determination of the prime objective must include the possibility of alternate solutions and I will try and show you.

If we go into an actual situation, then we have one of two possibilities. The answer to the equation "50 + 50 = ?" is "100" or you are wrong. In other words, we have no possibity of variation to the problem. But if I do this the other way around and said, "My equation yields 100, I want to solve this problem. How can I do it?" Well, if somebody says, "Two times fifty," he is correct. In one situation you would choose a two times fifty solution, other times you would take four times twenty-five, another, ten times ten. You obtain your objective by using various methods. This once again will be dependent on the situation at hand.

Now, I would like to look at one of the tools we can use in the development of a contingency plan and I would like very briefly to try and adapt this to the *Ocean Ranger*. One of the key words is identification. In developing a contingency plan one has to identify:

1. Situations – What can happen? How can it happen?
2. Problem and Priority Areas – Where can it happen?
3. Individuals – Who is to take action?
4. Duties – What to do?
5. Systems and Equipment – What to use? When to use it?
6. Procedures – How to do it? How to use it?

This is a tool that can be used for the development of a contingency plan by the individuals concerned.

Earlier we were talking about the man/machine interface and this is one of the major drawbacks that we meet in all forms of contingency plans. It is this complex relationship between the probability of an incident occurring (which you might call risk analysis), the possible cause, the courses of action and the individual or individuals who decide on strategy and the persons who have to carry out the physical operation. Emergency procedures are designed to cover the most probable incident and the most probable course of action. The major weaknesses of such plans is that they have to assume that the emergency will develop along certain lines; that the platform organization is intact; and that individuals will react in a calm and rational manner. As I said previously, if we tried to cover all possible situations, our plan would be so voluminous that no one would ever read it. A friend of mine said, "Our contingency plan is the most dangerous thing in the world. It's so big that if you drop it on your foot, you end up in hospital."

No two situations are ever quite alike. We do agree on that and in order to cover this we have developed a tool for carrying out what we call a table-top exercise. A table-top exercise can be literally no cost whatsoever and can be used as a tool to check your contingency plan. We at Elf carry out what we call safety tactical training courses where we bring the platform personnel together with the onshore emergency organization, the masters of the standby vessels and so on. Each person plays his own ro

and there is no time limit. We stop at each stage for discussion and we let people come out with their feelings. The first thing we do is determine the platform and we ask the people involved, "On your platform is there something that gives you the shivers, something that keeps you awake at night?" We use this approach to identify the type of incident.

Next we use a series of questions: Where on the platform would this take place? How would it take place? How many people would be involved in the accident? We discuss these items. We try to postulate the number of people who would be injured from the type of incident we could expect. We then ask the people to consider what they would do in such a circumstance. What about firefighting? Would you carry out a shut down? Would you carry out evacuation and how would your notification be carried out? We ask each individual, "Do you agree with what he says? Would you have done this in another manner?" And we check and go back and see what the contingency plan says. If people do not react according to the plan, it is either the plan or the people that are wrong. We have to correct this. If the people are correct, we modify the plan. If the plan is correct, we agree on that, then we have to retrain our personnel.

We then continue to the third stage where we add complications to the situation. The number of solutions identified to respond to these circumstances is really amazing. Man has the capacity to improvise in crisis situations. We did an exercise on one of our installations where we killed the platform manager, we killed his deputy, we killed the nurse, we killed the crane driver and we also put the sick bay out of operation due to fire, and they were left on their own. The way these people took over was really amazing. Although they did not have medical facilities and we gave them a great number of broken bones, they went into the galley and we had no broomsticks left, but we had an awful lot of splints. They improvised in a manner which was really amazing.

Even utilizing such a tool for training in crisis management, there are certain pitfalls. Consider the people who operate these systems, the people who are going to take over in the case of a system failure and the people who determine a plan of action. These are individuals who have all got their inherent weaknesses. I have seen different people react in different manners or the same man can react in a different manner on different occasions when faced with literally the same situation. Repeated training with no variation whatsoever will produce a sense of false confidence that everything will take place as it does during an exercise. An individual will develop a tendency, good or bad, to associate certain situations with certain results and if he gets into a situation he will try and adapt the situation to tie in with his solution and not his solution to tie in with the situation. If he cannot control this in the worst possible case, panic can be the result. This is what we refer to as a fixation. We look upon the members of a certain profession as having certain characteristics, qualifications, and abilities and we forget that these people are, in fact, human beings. They have their own reactions and they have their own feelings.

In his presentation Mr. McGrath made the following statement and I quote:

> The drilling contractor new to the area and working for an inexperienced operator is at a disadvantage in his ability to relate to the local conditions and regulatory requirements. The operator/contractor combination relies heavily on other experienced operators and contractors to share their knowledge. It is through this cooperative sharing of knowledge and experience that potentially catastrophic situations are averted and the learning courses are accelerated.

Well, in Norway we have tried to develop a standard contingency plan. We have tried to cover all forms of operations and a contingency plan relates really to four parts. First, the platform part which accompanies the platform regardless of the operator with whom it is working. The second part is designed by the authorities and other subcontractors. These parts dovetail together. In other words, I can have four rigs and my own fixed installations working but my procedures as operator are the same.

These dovetail with our own fixed installations and the platform clients. We have a common indexing system for each document. Then we define the emergency organization of each of these plans. The only external authority is the main Rescue Coordination Centre's organization and the government action control group that takes over. We have standardized situations so that chapter 41 in every contingency plan is a fire explosion, 42 a gas fire, 43 a helicopter on deck and so on. The reason we have done this is that in certain situations (diving and radiation accidents) it is the subcontractor who is best qualified to do the job and is responsible for that contingency.

I would not necessarily say this approach to contingency planning is the way you should do it here, but it is the way we seem to have solved some of the problems that you encounter here. It is a tool that one might utilize.

COMMENTARY ON PAPER E

F. Williford
Assistant Vice-President
SEDCO, Inc.

I am fortunate in that I know a number of people in the audience today. I have spent a number of years working in this part of the world and resided on the East Coast for a total of about five years. So, I ask that you listen to what I have to say today and remember I am bringing some experience but also a fairly narrow perspective to the problem we have at hand. The theme is safety; the specific topic is organization and management.

As a Drilling Contractor, I own the vessel, I operate it, and I employ the labour force. I am directly or indirectly responsible to four federal agencies, three provincial agencies, and five operating companies. I am being viewed with a critical eye from a number of directions and I can assure you I feel the pressure. At the end of the day, my only claim to fame, in fact, will be how much hole I managed to drill in the ground with, hopefully, no claim to any notoriety. I will not likely get much credit for the number of people hired or trained. I will only be told that I must do so in a credible manner. Fortunately, we have mutual requirements in this regard. I need a lot of good, well trained people and I am actively engaged in looking for them every day. There will only be a limited understanding of my needs and requirements for others, but I must understand the objectives, the needs, and the requirements of the host governments and the operating companies. Therefore, I appreciate with all due respect a good operational contingency plan. That is something I can understand and that is something I can respond to, because I do it everywhere I go. I must, however, have the flexibility and the freedom to run my own vessel and to train my people so that they suit the needs of my operation and perform in accordance with the characteristics of my vessel. Governments, rightfully so, advise, regulate, check, inspect and control a lot of the aspects of the workplace. I require that the operating company and the government entity provide me with an atmosphere and a scenario that allow me to respond to the job I am hired to do.

I support safety emphatically for good reason. I am really not misguided in this regard, because I spend far too much time out on the drilling vessels. If something goes wrong, I will surely be personally involved. I cannot escape this involvement. I can assure you that I have complete understanding and a desire to further the outline presented in Mr. McGrath's paper today, because the contractor knows the problems faced by the operator and he knows why the operator hired him. He knows that the job at hand is to work in the safest and most efficient manner if he is going to stay in business.

Summary of General Discussion Following Paper E

Mr. I. Manum (Norwegian Maritime Directorate) agreed with the importance of employing well trained and skilled personnel offshore, but he questioned whether the persons chosen for the most important positions actually possess the best and most appropriate personal qualities and capabilities. He cited the *Vinland* blowout incident, the investigation of which indicated that the person in charge had not used appropriate judgement in closing down the well. Mr. R. McGrath (Petro-Canada) disagreed with Mr. Manum's assessment of the *Vinland* incident, and added that an operator expects the drilling contractor to make available the most competent and capable people to fill the key positions on a rig. Mr. F. Williford (SEDCO, Inc.) said that this aspect is admittedly difficult; SEDCO goes to great lengths to avoid inflexible career paths for its employees and tries to identify capable personnel as early as possible so that proper training can assist them to rise to top, responsible positions.

Session Chairman Dr. G.M. MacNabb wondered about the relevance of physical and psychological competence of the people who are in key positions. Dr. H. Haakonson (Petro-Canada) responded that, in addition to identifying capable persons, companies should have some sort of mechanism in place which will allow personnel to identify their own capabilities (or lack of them) on a day-to-day basis.

Dr. B.P.M. Sharples (Noble, Denton) expressed concern over the practice of a drilling man being in charge of an offshore rig, only to have someone else take control in the event of an emergency. He wondered how this change of command is communicated to the crew and how emergency situations are identified. Mr. McGrath replied that, while the present situation is not completely desirable, industry is searching for a better solution. He described the following command structures: 1) on a dynamically-positioned drill ship the master is always and continuously in charge; 2) on an anchored drill ship the master is always in charge although he delegates this responsibility when the unit is in the drilling mode; 3) on a semisubmersible the master is always in charge for the safety and well-being of the unit, even though a drilling man may be the apparent man in charge when the unit is anchored and in a non-forward motion; 4) on a jack-up the drilling man is in charge when it is jacked-up into a stablized position. There is, however, a formal signover of command to the master when the jack-up is to be towed or re-located. Mr. Williford supported the explanations of Mr. McGrath and said that, although the drilling people are in charge of daily drilling operations, there is never a point in time when the master is not in charge of the vessel.

Dr. J.R. Hawkins (Esso Resources Canada) made reference to the keynote address of Mr. G.R. Harrison and questioned the advisability of charging the chief executive officer of an operating company with the ultimate responsibility for all aspects of engineering and safety operation in offshore drilling ventures. Mr. McGrath agreed with Mr. Harrison's idea of single-point responsibility, adding that a varying scope of single-point responsibility normally occurs at each of the management levels of an organization.

Vice-Admiral A.J. Fulton (CAF, retired) raised the question of the maintenance of an appropriate level of physical fitness of offshore workers as one aspect affecting their ability to perform routine and emergency duties. Dr. Haakonson indicated that, in his experience, most workers are very keen to learn and do whatever is required to maximize their ability to survive in the case of a disaster. Any program to increase the level of fitness of offshore workers would be limited to emphasizing the impact of fitness on the chances of survival. Mr. J. Hielm (Elf Aquitaine Norge) added that Norway requires all offshore workers to meet the terms and conditions of a health certificate, and that includes consideration of the physical weight of a worker. If the worker is judged by the examining physician to be too overweight, the worker is denied the right to work offshore. Dr. C. Brooks (DND Maritime Command Headquarters) indicated that the fitness of an individual to do a specific job may be a problem, and he suggested that varying physical fitness criteria will need to be identified for various types of positions to overcome this problem.

Mr. R.E. Johnson (NTSB) raised the subject of contingency plans and how the operators and contractors integrate their plans so that no confusion results during an emergency. Mr. McGrath responded that the regulations require the operator to submit a contingency plan for each drilling location. Upon approval by the regulatory authority, copies of the plan are placed in the operator's office on shore and on board the rig to be used to ensure that everyone who has a role in that contingency plan is aware of it. Mr. Williford pointed out that, as a drilling contractor, SEDCO establishes a vessel-specific contingency plan, adapts it to the particular environment and jurisdiction of the drilling program being undertaken, and then blends it with the needs of the operator. SEDCO also takes into consideration other equipment which may be available in the field, outside that provided by the operator. This integrated plan receives formal agreement by both the operator and the contractor.

Mr. J. Hornsby (CCG Ship Safety Branch) pointed out that the *Ocean Ranger* had contingency plans which were essentially ignored, and prior to its capsize, the *Ocean Ranger* was considered a successful vessel. Industry must assure the regulatory agencies, he said, that these plans are more than mere paper protection and that reporting procedures are being adhered to, thus enabling the regulatory agencies to monitor the rigs' actual safety performances and procedures.

Mr. McGrath again emphasized the importance to industry of the guidelines provided in a contingency plan. With regard to the reporting of incidents, he pointed out that the regulatory authorities have yet to define incidents which are "reportable" and not subject to interpretation. These differences need to be worked out to the satisfaction of both the industry and the regulatory authorities.

Mr. Johnson also raised the issue of the need for the establishment of qualification standards for rig workers, and asked what has been done by industry, particularly in the United States, in this area. Mr. McGrath said that, in Canada, the person in charge must be a master with more than four years experience on a vessel greater than 25 tons. Mr. Greif (SEDCO, Inc.) referred to a recent document in which the Canadian Association of Drilling Contractors agreed to job descriptions for various positions on a rig and applied minimum levels of training, education, certification and testing to each position. In the United States, a similar document, produced by the International Association of Drilling Contractors, will be presented to the U.S. Coast Guard in an attempt to have greater industry input into the licencing and certification of personnel. When asked by Dr. MacNabb whether these standards also address the degree of physical capability required in certain positions, Mr. Greif replied that they did not, because, as stated earlier, this has never been a problem. The IADC document emphasizes skills such as ballasting, weather forecasting, and dealing with emergencies.

In the United States the person in charge of a rig, in most cases, is a drilling man with experience and tested skills in marine matters and who holds a Column Stabilized Masters' Ticket. The industry has encouraged the Canadian Coast Guard to investigate and consider this approach and to work with the U.S. Coast Guard to develop a similar standard for Canada.

Mr. H.L. Zinkgraf (SEDCO, Inc.) interjected that approaches to Canadian Coast Guard to participate in the talks between industry and U.S. Coast Guard regarding qualification standards have had no response to date, as far as he was aware. He felt that this is unfortunate as it has hindered the possibility of developing a North American standard of qualifications for key offshore positions. Mr. Hielm alerted participants to the importance of differentiating between skills and certification, and referred to an incident in Norway when Red Adair was asked by authorities to kill a well at Ekofisk Bravo but was not certified to work on the Norwegian Continental Shelf.

Mr. R.A. Quail (Canadian Coast Guard) asked Mr. McGrath for clarification of what is meant by a "certification program", would it be part of a regulatory system, and if not, how would such a program be administered and enforced? Mr. McGrath felt that a program where individuals are "ticketed" as being qualified to command certain positions, would be workable through present regulatory agencies.

Mr. Johnson outlined the problem with highly technical data, particularly stability data, being made available to operators in a form which is too sophisticated and complex to be of real use. Mr. Zinkgraf explained that SEDCO requires its ballast control operators to have a fundamental understanding only of stability and hydrodynamic theory. SEDCO has various levels of sophistication in its training of ballast control operators, depending on the locale: in Aberdeen, an academic course, which ballast control operators from SEDCO's North Sea operations are required to pass, is offered through the Robert Gordon's Institute of Technology; in both Aberdeen and Dallas, SEDCO teaches a basic, in-house stability course to its permanent staff members (this has also been taught in St. John's); and, in Dallas, SEDCO has developed and will soon be using a ballast control simulator which has been designed to incorporate vessel-specific motion response characteristics.

Dr. G.P. Vance (Mobil Oil Canada) asked how a crew should respond to the multifaceted priorities of budget, training, safety and performance. Mr. Williford believed that perception of these priorities was different for the contractor, the operator, and the regulators. SEDCO, as a contractor, plans its programs in a manner which best conforms to the local situation, while keeping in mind that the safety of a whole rig is an all-encompassing factor.

As far as the safety of each individual is concerned, Dr. Foley said that individual perception of the priorities tends to be guided by cognitive locking, a process whereby the individual focusses on one aspect of a system to the exclusion of everything else. The cause of a particular item of focus, however, cannot always be easily explained; it could be the result of intensive training or propaganda, and occurs particularly during emergency conditions.

Dr. B.P.M. Sharples (Noble, Denton) asked about the role of rig day rates on total safety, and suggested that perhaps the establishment of a minimum rate would ensure a certain standard of overall safety. Mr. Hielm said that Norway approaches this problem by having a cost benefit analysis conducted for changes put forward by government. If the costs far outweigh the increase in safety, the change is not considered worthwhile and it is not required to be implemented.

4

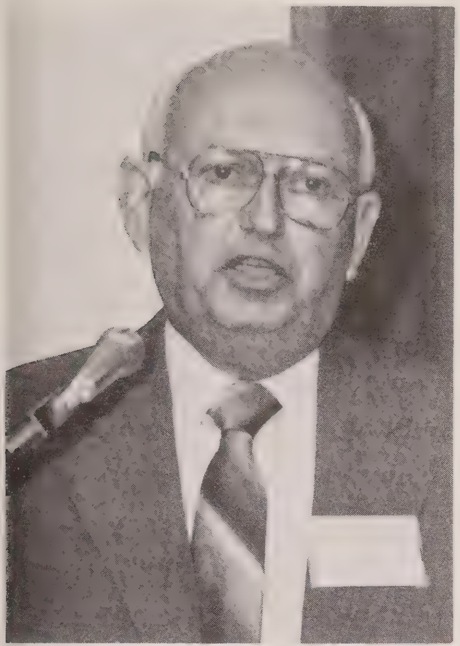
EMERGENCIES

EMERGENCIES

INTRODUCTION

The studies of emergencies examined the capabilities of existing evacuation systems for MODUs and the research and development which is underway into new and innovative methods of evacuation. As an adjunct to this, the systems for ensuring survival following evacuation were also examined, as were the response and rescue procedures and facilities that are provided by both industry and government.

This Technical Session was chaired by Dr. A.J. Mooradian, who has extensive experience in all aspects of the nuclear industry in Canada. He holds degrees in Chemical Engineering and Physical Chemistry, and joined the Chalk River Nuclear Laboratories in 1950 to work on plutonium separation with the Chemical Processing Group. Through the following years Dr. Mooradian held a number of senior positions with the Chalk River Nuclear Laboratories and the Whiteshell Nuclear Research Establishment, and in 1982 he was appointed to his present position of Senior Vice-President over both those organizations.



Mr. C. Shaar
President
SeaTek Corporation

Mr. Shaar holds an M.Sc. from Rensselaer Polytechnic Institute. From 1954 to 1961 he worked with Bendix Systems Division; from 1961 to 1976 he was Manager of Delco Electronics in Santa Barbara, and was responsible for the development of the Delco Dynamic Ship Positioning System. He also developed and built the lunar rover for NASA. Mr. Shaar is currently President of SeaTek, a company he founded in 1976.

PAPER F

Escape and Survival

INTRODUCTION

It is generally recognized that evacuation and escape from a mobile offshore drilling unit (MODU) in an emergency situation is an extremely dangerous process especially in very cold, stormy environments. It is also a matter of record that in the recent past several major MODU disasters have resulted in the loss of a large percentage of the personnel involved. The purpose of this paper is to discuss some of the important factors which affect the probability that personnel can escape and survive, and new equipment developments, which might improve survival probability. To accomplish this objective, a review has been made of the many excellent reports on recent marine disasters and discussions have been held with the U.S. Coast Guard, oil companies, drilling companies, and lifeboat and davit manufacturers. During this review process, it very quickly became apparent that there is general agreement as to the nature of the problem and the particular areas in which new engineering developments might improve the situation.

ESCAPE AND SURVIVAL

The Problem

In the case of a MODU, operating in Canadian or similar waters, escape and survival is made extremely difficult because of the environment. Even in the best of weather, high winds and rough seas are frequent and seas are cold. In addition, the practical stowage locations for survival craft and liferafts on MODUs are high above the water surface, 10m to 35m is typical. A further difficulty is that the MODU structure, between the main deck where the survival craft and liferafts are stowed, and the sea is quite open, and a lee from wind and sea cannot be provided.

Factors Affecting Survival

The primary factor affecting survival chances during an emergency evacuation from a MODU is the method of evacuation. A helicopter is preferred universally and is by far the safest means, if it can be used. If evacuation and escape by sea is the only choice, then the probability of survival is influenced by a number of factors which include, but are not limited to:

- The weather
- The nature of the emergency
- Training of the crew
- Placement, number and types of survival craft and means of deployment
- Protection from the cold by the use of exposure suits
- Communications
- Availability and capability of Sea Air Rescue

Most authorities, however, agree that there are four areas in which equipment design improvements would have the greatest impact on improving the survival of the personnel involved. These are:

- Lowering the survival craft
- Release of the survival craft from the davit falls for both on-load and off-load systems
- Moving away from the platform
- Recovery of personnel from the survival craft

Industry Reaction

Since all of these problem areas are widely-recognized, it is reasonable to ask what is being done about them. In Norway, the response has been a major government-funded research and development project which has resulted in what is now the Harding free-fall lifeboat. There are some critical comments which can be made regarding this new system. They include the fact that it is heavy, expensive, and possibly difficult to launch at moderate angles of heel or trim. Also, the idea of free-fall from great height presents a serious psychological problem for many potential users. Nevertheless, at this point in time, it is probably the best available solution to the escape and survival problem. Manufacturers of the conventional totally enclosed motor propelled survival craft (TEMPSC) have, on the other hand, tended to work on parts of the problem with the intention of improving existing systems. Some of this work, such as the Watercraft PROD, has been excellent. Nevertheless, no major new system development seems to have been initiated.

POTENTIAL SYSTEM IMPROVEMENTS

The conventional TEMPSC could become a much more effective means of escape and survival and a viable alternative to the Norwegian free-fall boat if a major system development is undertaken which addresses the four problem areas already identified as critical, namely, lowering the survival craft, release, moving away, and recovery. A review of these design problems will show

that what is needed is a good deal of engineering work and little or no invention.

Lowering and Release of the TEMPSC

The greatest danger to the survival craft during lowering on the davit falls and release from the davit falls is collision with vessel structure which results in damage to the survival craft and injury to the passengers. Because of the davit height and wind and wave induced motions, the survival craft can be expected to be swinging on the davit falls through a wider and wider arc as it approaches the sea. Collisions with vessel structure are possible, and the system must be designed to avoid them, if possible, and to survive them, if they occur. The best means of avoiding collisions with vessel structure is to cantilever the survival craft as far away from the ship's structure as possible and pointed away from the vessel. This method has been adopted in many modern semisubmersible designs. An alternative is a gravity-powered, articulating davit which would accomplish the same purpose. The best such device, which we have seen, is a new development by Kosafe A/S of Halden, Norway. The action of the davit is shown in Figure 1. An important feature of the davit is that it automatically senses the horizontal and lowers to that position. The development of this type of davit should be pursued unless a better equivalent solution can be found.

In high winds and seas, even if the maximum clearance has been achieved by davit or cantilever, swaying of the survival craft in the davit falls can result in collision with MODU structure and this problem becomes more likely as the survival craft descends and the length of the davit falls increases. It is, therefore, important to minimize the time required for this process with davit winches which will lower the lifeboat toward the sea at a reasonably rapid rate. In addition, in our opinion, release of the survival craft should be accomplished 10 to 30 ft. above the water surface, using releases which operate under load. The use of on-load release is not inconsistent with either current I.M.O. recommendations (5) or U.S. Coast Guard findings (4). A program of rapid lowering on winches, followed by a short free-fall, would require several major design changes in the survival craft. These must include strengthening the basic structure, proper restraint of passengers to protect them from accelerations which would cause injury and a means of controlling the impact deceleration at the time of water entry.

The structure of many of the survival craft in use today needs to be strengthened. There are ample reports of damaged survival craft structure to justify this conclusion, including the *Ocean Ranger* case (6). The specifications to which the fiberglass reinforced plastic hulls are built in the U.S. are given in the *U.S. Code of Federal Regulations* (7) and in Military Specification P-17549D (SH) (8). A Grade 3 laminate is specified (7) and is defined as (8):

> Grade 3 is a medium strength, bi-directional or isotropic laminate reinforced with style 7544 woven glass cloth or equivalent or random glass mat.

The structural strength of this laminate is specified as 31,000 lbs/in^2, whereas, better grades are of the order of 50,000 lbs/in^2. Many of the survival craft in use today use the "random glass mat" which consists of randomly-oriented short pieces (one or two inches) of fiberglass. Multiple layers of woven glass cloth are a superior structure. Not only should this type of structure be used, but there should be a specification on the number of layers and type of lay-up, as well. This construction is used in many U.S. Navy small boats, including U.S. Navy whaleboats and should be used on MODU survival craft.

The accelerations to which survival craft passengers may be subjected during lowering and release are a serious problem, and they are not properly provided for by the seats and seat belts in current survival craft. The accelerations which must be guarded against during impacts with ship's structure are not specified by I.M.O., although a 3.5m/s impact velocity is given (5). However, accelerometer instrumented tests of current lifeboat designs were conducted by SeaTek. Tests at a drop height of 10 ft. (the U.S. Coast Guard test required of all survival craft) showed that peak accelerations could easily reach 20 g's. A typical test record is shown in Figure 2. Figure 3 shows the acceleration range which is acceptable for a human passenger, seated in a conforming cushioned seat and restrained, with both lap and shoulder harness (9). Without these restraints, serious injury is likely at much lower accelerations than experienced in a 10 ft. drop.

If the survival craft and its passengers are to survive the accelerations they will likely experience, at least two changes should be considered. First of all, the interior seating and passenger restraints of the survival craft must be redesigned to provide conforming seats and proper passenger restraints. This will result in a decrease in passenger capacity of any given survival craft of about 15%. Secondly, a means should be provided to reduce accelerations at the time of water impact after an on-load release from a height of as much as 30 ft. Devices which will do this and which are attached to the keel of the survival craft and can be dropped after water entry have been su cessfully tested by SeaTek Corporation ar others. The SeaTek device, when subjecte to a 30 ft. drop on a 28 ft. Watercraft su vival craft, resulted in very low acceler tions, as shown in Figure 4.

In Figure 5, a water entry system (W.E.S designed for a 90 ft. drop height and su cessfully tested in full scale at 60 ft. can b seen. A W.E.S., designed for a 30 ft. dro would be significantly smaller. If an on-loa release from known, but small, height abo the sea is to be routinely used, then a re able height measurement is needed. The are several approaches which can be use Von Tell/GVA have used a thermist extending below their "Lifescape" to pe form this task. A bubbler type of pressu measurement would also be possible. It probably desirable to investigate both typ of device.

Moving Away from the MODU

Once in the sea, the problem is then escape from the vicinity of the MODU wi out being pushed back against the vess structure by wind or wave action. Surviv craft, especially when loaded with passe gers, are heavy; 14,000 lbs. is not unusu The engines in current models are not hi powered: 40 to 80 H.P. is typical and sta ing may not be reliable. In storm seas, wa particle velocities in waves can be 20 ft/s or more, and the threat of collision with t vessel structure could be great. The PRO system now being developed by Watercr is the best potential solution to this proble that we have seen. It can probably be us with any form of survival craft stowage. used with a davit, such as the Kosa design, the PROD boom could be attach to the end of the davit as shown in Figure

Recovery of Personnel from the Survival Craft

The survival craft should be designed a equipped so that once it is safely away fro the MODU the occupants can survive ur seas abate, however uncomfortable th may be. Recovery in storm seas is such hazardous operation that it should attempted only if waiting is not possible.

FULL SCALE TESTS AT SEA

Naval architects normally use a wave bas as a guide in developing their designs. T wave basin has also been a useful tool studying survival craft problems, such as t Watercraft PROD and the SeaTek W.E. However, a very strong case can be ma for a series of instrumented, unmanned, f scale tests of any new TEMPSC, includi

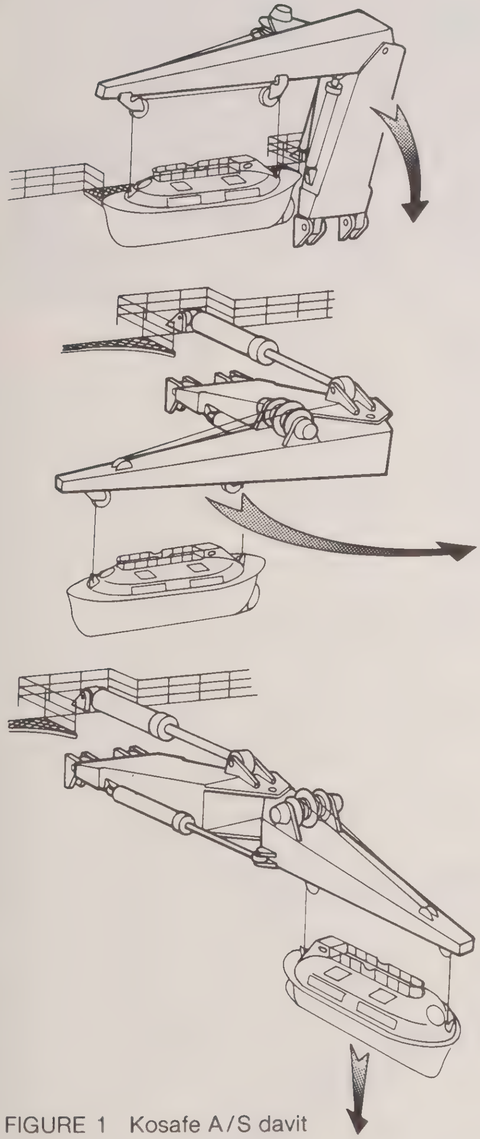


FIGURE 1   Kosafe A/S davit

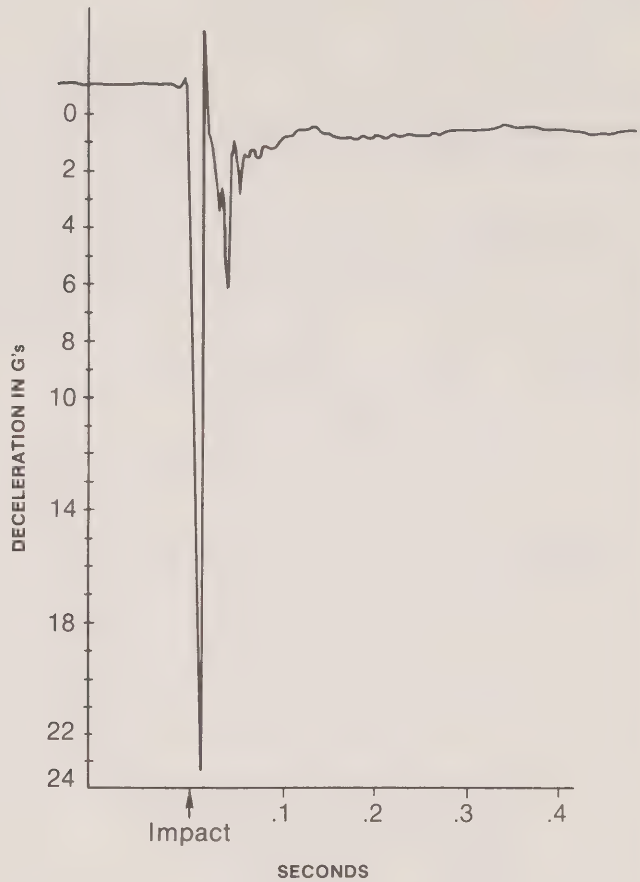


FIGURE 2   Deceleration of survival craft during 10 ft. drop to water surface

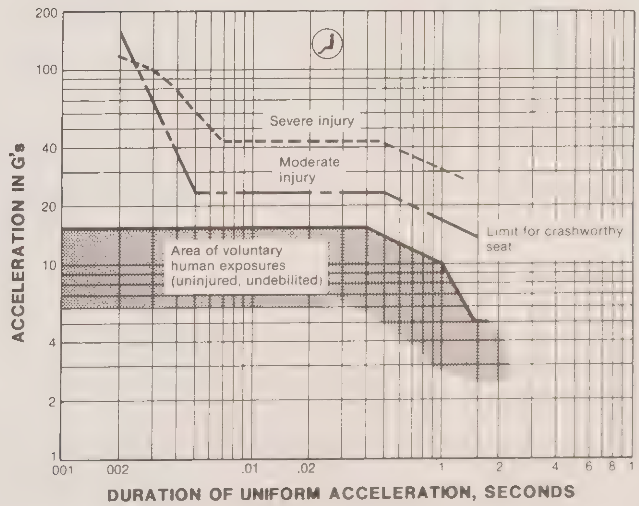


FIGURE 3   Duration and magnitude of headward acceleration

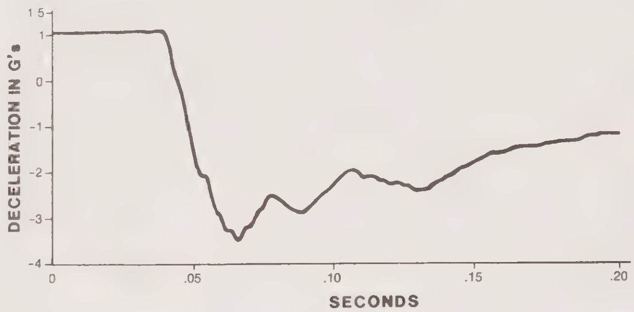


FIGURE 4 Deceleration of survival craft during 30 ft. drop to water surface with water entry system

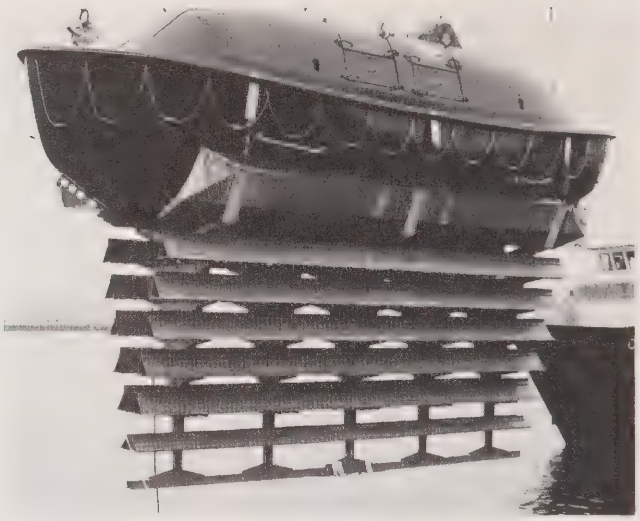


FIGURE 5 SeaTek water entry system designed for 90 ft. drop height on Watercraft TEMPSC

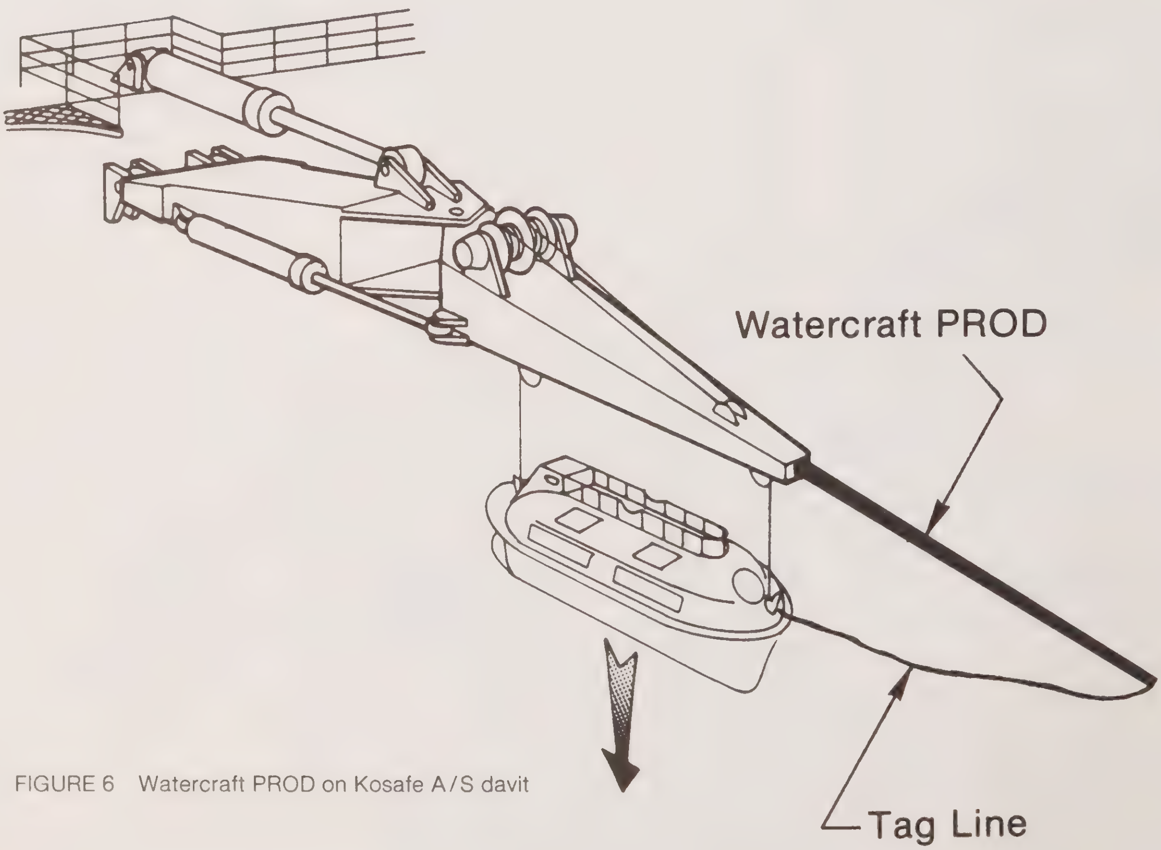


FIGURE 6 Watercraft PROD on Kosafe A/S davit

the Harding free-fall system, by deployment from a MODU into storm seas. The TEMPSC is, after all, a complex system for saving life in emergencies at sea. A series of instrumented full scale deployments of TEMPSC, which are tracked and recovered, would not only show up equipment problems, if any, but would yield information difficult to obtain in a wave basin. Water particle velocities in storm seas can be 20 ft/sec or more, and this combined with high winds and breaking waves could cause problems at water entry, during escape from the rig and for survival in the open sea. These tests can easily be instrumented so that the survival craft steering and engines are controlled by the recovery vessel, and there are several ways of maintaining a continuous track on the TEMPSC until it is recovered.

SYSTEM DEVELOPMENT

It is our conviction that no major new TEMPSC system development will take place in industry unless something deliberate is done to bring it about. In the case of Norway, the impetus was a government-funded research and development program which resulted in the free-fall Harding system. The U.S. Coast Guard seems to have recognized this mechanism as possibly required by stating (4):

> The problem of lowering lifeboats and life rafts from MODUs, due to the heights involved and due to the lack of a lee because of the open construction of the rig, has not been satisfactorily solved. A joint government-industry effort on an international scale, through the International Maritime Organization (IMO), should be initiated to address this problem.

We feel that joint international programs are cumbersome, and at least in the U.S. would like to see a government development administered by the U.S. Coast Guard.

Advocacy of a government-sponsored development project should not be interpreted as a criticism of industry. It is, perhaps, a criticism of the entire system within which we all work in the offshore industry. The drilling contractors and oil companies both resist the application of new government regulations, and this is understandable. Yet while the offshore industry has exhibited great talent in solving drilling and production problems, improvements in the quality of TEMPSC installations have not kept pace. The TEMPSC and davit manufacturers have no ready means for introducing radical change. When they bid on TEMPSC, it is usually a competitive bid to the existing specifications and the low cost bidder gets the job. This is one reason for the rather widespread use of "random glass mat" in survival craft structure and the use of the simplest possible personnel restraints. A major factor which would seem to argue for a government-sponsored development is the cost. The system required involves new survival craft hulls and structure, man rating of new personnel restraints, probably new davits, and expensive full scale tests. In addition, new government regulations must be put in place to require use of the new system once it has been developed.

CONCLUSIONS

A review of the available literature has made it clear that there is general agreement on the problems which must be solved to improve the probability of survival if an emergency requires escape by sea from a MODU in Canadian waters. Some engineering solutions have been suggested, and there are, undoubtedly, other alternatives. In fact, it seems clear that considerable progress can be made with a well-directed engineering effort. Invention is not required. The major obstacle seems to be the creation of a mechanism within our offshore industry and our respective governments to make it all happen.

References

(1) Technica. "Risk Assessment of Emergency Evacuation From Offshore Installations" a study carried out for the UK Department of Energy. London, September 1983.

(2) Joughin, R. W. "Ship Operators View of Failings in Design of Survival Craft" a paper delivered at the RINA Conference on Marine Survival Craft. London, November 14-16, 1983.

(3) Hollobone Hibbert and Associates. "Assessment of the Means for Escape and Survival in Offshore Exploration Drilling Operations" a report prepared for the Royal Commission on the *Ocean Ranger* Marine Disaster. January 1984.

(4) U.S. Coast Guard. Report No. USCG 16732/0001 HQS 82, "Marine Casualty Report Mobile Offshore Drilling Unit (MODU) *Ocean Ranger*." May 20, 1983.

(5) I.M.O. Revision of Chapter III of 1974 SOLAS Convention.

(6) Government of Newfoundland and Labrador. "Technical Investigation of *Ocean Ranger* Accident." April 1983.

(7) U.S. Code of Federal Regulations, Vol. 46, Subpart 160.035 pages 120 to 142. October 1, 1981.

(8) U.S. MIL-P-1754D (SH). "Military Specification: Plastic Laminates, Fibrous Glass Reinforced, Marine Structural." August 31, 1981.

(9) U.S. Air Force MIL-S-04793

COMMENTARY ON PAPER F

Dr. C. Brooks
Command Surgeon
Maritime Command Headquarters

About February of this year, Dr. Solandt came in my office and said to me, "I know you are interested in escape and survival. Would you please come along and be a discussant at our *Ocean Ranger* meeting? We would like you to give us some provocative comments." So, I will do just that for you, Dr. Solandt.

Mr. Shaar, I was delighted with your paper, and what I am going to say is actually going to compliment you on your paper.

Your SeaTek system has really taken a technology which is Second World War and improved it somewhat, and really if we are truthful about it, it maybe is not going to work as well as it should do. I think that the time has come when we have to take the leaf out of the book of our aviation life-support group of companies, and let me give you an example of this.

An RAF Lightning on the approach to Farnborough just before the practice for the International Air Show was at about 350 to 400 feet when it ingested a large bird and the pilot had to get out. To activate his ejection, his seat was broken away, his parachute deployed, and in about three seconds, he landed on the ground safely. That is 1950s technology. Since then it has been quite normal for high speed, low level flight aircrew flying at 450 to 550 knots, at 100 feet above the deck, to eject. They get out and we save the majority of them. Admittedly, a few of them have a compression fracture of the spine, a few have dislocated elbows, but the point is this that they are all very alive and well now. The initial injuries they had were very survivable and we have got them back.

With our new CF-18 aircraft we are in the lucky situation where if the airman is on the runway, maybe travelling along at 70 knots just before take-off, and he has a fire on board, instead of having to put the aircraft to a full stop, take down the quick release box, remove his communications, his oxygen, climb over the canopy, having jettisoned the canopy, jump 8 feet 6 inches to the ground from the leading extension to the wing, he just pulls the ejection seat handle and within three seconds, not only is he up 250 feet in the air, he is in a full deployed canopy and back down on the deck again. That is the sort of technology that we have.

Really what I am saying to you is, that I think that we should be looking at that as an option for launching people from a 100 foot MODU in a storm. It is only one logical step further to get the technique to do this. It h
great advantage: we get well away from t
rig, we do not have to start engines up, v
do not have the problems of icing with
and last but not least, once it is in the wat
it acts as its own protective shell where t
people can survive until a helicopter can g
there when the storm abates. The imme
ate disadvantage to this, and I can hear t
oil companies squealing like crazy now,
that it is going to cost a bundle to do th
But I am not sure that it is. We went arou
the beautiful facility of the wave maki
tank and I am sure that with less mon
than that, we could have a superb situati
where we could have such a system. Th
would do for all sorts of other marine cra
particularly well for people in the Arctic Se
where they will have to land on ice mo
likely.

I maintain, because of maritime disaste
that have always been with us, and that
has always been taken as an act of Go
fate, and part of the job that we lose pe
ple, that both government and industry ha
never really put as much money into looki
at proper equipment for these people an
think that it is about time they did so.

My second question concerns training. W
have talked a lot about training this mo
ing. An escape system is only as good
the training system you have on board yo
vessel. If I owned the rig, I would not ha
anyone on board unless he had be
through flooded compartments, unless
had shown me and the regulators that
could behave in a correct manner in bei
able to escape from it.

I also question the problem of whether
should allow on rigs people who cann
swim. Let me just talk a little about drow
ing. You are probably aware that the he
has a thing called the vagus nerve; it is t
main electrical piece of string between t
brain and the heart. This nerve has o
strange condition when you stimulate
instead of speeding up like every oth
nerve in the body does, it slows down. S
you have a condition where people, wh
they are immersed in cold water, the co
water driving up into the nose and into t
throat stimulates these segments of t
vagus nerve, and slows the heart, and ev
stops it. We have another condition whe
in stages of extreme fright and terror, the
is a considerable amount of adrenalin ru
ning around the system and that pred
poses the heart to an irregular beat or ev
predisposes it to stopping. What I am rea
saying to you is, when we have a treme
dous catastrophe occur to someone, the
guys who have never been in water befo
who are frightened of water, when
plunge them into cold water, even with t
best life preserver around, even with t

best immersion suit around, they are basically going to be dead when they arrive in the water.

I think it is also time we looked at training our senior operators in when to abandon rigs. I think that some people amongst us would believe that there is a great amount of just simple seamanship here and if someone had made the right decision to stop drilling and get the hell out of it, we would not be here today discussing it all.

I would like to make an observation on our helicopters. We spend an awful lot of money with Dilbert dunkers and HUET dunkers, getting people to escape from them. We all know perfectly well that when you dunk a helicopter into the water it immediately rotates and we have to get people out from an inverted helicopter. I wonder why the oil industry who must have a huge lobby, do not go to the big helicopter manufacturers, and ask them to design us a helicopter right from scratch which will float if it goes into the water, or if it will not float, why on earth can we not blow off the top of the helicopter? We have miniature detonating cord around now and that takes care of pieces of canopy so we can eject through them; it is only a little bit of further technology to do this sort of thing.

I am going to get on a little pet subject of mine now, and that is immersion suits and dingies. I am going to tell you a few truths about them. First of all, we do not have any new technology in materials at all. In fact, the old 28 Frankenstein material that was invented in 1940, the breathable fabric, is still the best that we can provide. I am afraid that Goretex and all of these things really have shown us no advantages over old 28. We have a problem obviously, with the only way you can make a neck seal is to have a complete rubber ring around the neck. People have tried, and they keep bringing to me, different immersion suits with split neck seals. Well, we have a problem of human engineering here. We have an Adam's Apple which completely wrecks any fit if we try to split it. It is just a physical impossibility to get a neck seal. The only way we can make a neck seal is to put on a complete hood and bring out a zip which comes out about the side of your ear. Now we all know what happens when we give equipment to operators that they do not like wearing; they do not wear it. So we are wasting everyone's time. We have to look technically at new sorts of immersion suits.

Further with immersion suits, when you take a look at some of the ship abandonment suits, they have something in the order of 30 pounds of inherent buoyancy in them and they have no selfrighting characteristics whatsoever. You have got to put on something like a Beaufort Mark 29 life preserver with a 45 gram charge of CO_2 on board to get a self-righting moment. Now you take that and I just wonder if any of you guys here have tried to scramble into a dingy with something like that on, in the pool, not in a force six or a force seven gale. It is physically impossible, you have to take your life preserver off. It is absolutely exhausting doing it. So we have to spend a lot more money on looking at new materials and new methods of survival suits.

I said I was going to be deliberately provocative, and I am going to fire my last "salvo" now. As a Navy man, I have to confess it is another leaf out of the Air Force's book. The Air Force has two positions within their squadron operation which have a tremendous impact on their equipment. One is what we call the Base Flight Officer and the other is called the Life Support Equipment Officer. These two people, it is their secondary task, and a very definite secondary task, in other words, it is not the last of about 15 tasks to do, and so it gets that amount of priority, these two people have immediate connection with both their Squadron Commanding Officer and their Base Commander. If they feel strongly enough that the operation should stop because it is in some danger, then they will approach the Squadron CO and he will stop things until they get things going and they get new equipment or a change. I would say that is one of the reasons why the aviation industry generally has far better equipment than the maritime environment. I would recommend these people to offshore oil business.

COMMENTARY ON PAPER F

D.J. Riffe
Senior Project Engineer
Gulf Oil Corporation

The disaster last week off the coast of Brazil clearly indicates that the development and implementation of emergency egress equipment has yet to be perfected. The loss of 40 lives, at last count, was not due to the blowout which occurred on the *Petro Bras* platform, but due to personnel attempting to escape from the platform in an open lifeboat. All men aboard the boat apparently drowned as a result of the lifeboat capsizing in the rough seas.

The escape from a platform is very demanding, physically and mentally, because of the circumstances required for escaping from the facility. The escape from the platform must be simple, fast, and above all it must be safe. The use of the free fall or drop systems requires that all the crew members be seated and strapped in prior to descent of the craft. The fact that personnel inside the craft are human presents a situation where some of the crew members may not be strapped in, if a panic-stricken crew member prematurely releases the craft. The impact of the boat, be it 3 G's or 12 G's, will most likely result in injury to those crewmen who have not been strapped in. A horrifying example of this was the incident which occurred on the *Ekofisk Alpha* platform in the North Sea where three men were killed because they were not strapped into their seats when a panic-stricken crew member released the hook mechanism and the capsule fell approximately 20 meters into the water. To illustrate the horrifying tragedy of this incident, two of the three men who were killed were found with their heads in their chests because of the tremendous impact.

For restraining its passengers safely, the free fall lifeboat is equipped with a harness which is placed over the chest, waist, and shoulders, with perhaps the most alarming restraint being the band which pins the head to the seat to avoid neck injury. This restraint gives the rightful impression that one is embarking on something which could be potentially very dangerous, if everything does not go in the logical order. Having ridden a free fall craft a few years ago, I can assure you that the falling and impact rival any amusement park ride, with the exception that the amusement park ride has the capability of controlled descent and it is possible to get off the amusement park ride after a short period of time, which is not necessarily the case when you are in a fre fall lifeboat. It is interesting to note that ps chological research has shown that it is n the impact but the free fall that is the mo concern to the crew members.

The Harding craft will completely immers under water following impact. The fact th the boat is underwater for a short period time has presented the question of contr during this period, particularly in rough se conditions. To my knowledge, testing rough sea conditions, similar to those whic occur in the North Atlantic and the Nor Sea, has not been conducted. Questior regarding the performance of this craft harsh sea and wind conditions still rema unanswered.

Admittedly, there is a lot of researc underway which takes a close look at th particular problem area, but as yet there a no ideal escape craft available. Several ne techniques presented not only fail improve egress capability but worsen These concepts must be tested under th extreme conditions before approvals shou be given. In the case of the free fall craft, one really knows if it will perform th required task in an emergency. We may fir that the free fall craft would not have bee the answer to the problems encountered the *Alexander Kielland* and the *Oce Ranger* and might, in fact, have been det mental. The keys to any safe launch are th disengaging apparatus, the assurance good maintenance, the proper care of th apparatus, and the training of personnel understand the operation of the cover lifeboat.

There are problems with emergen egress other than the lifeboats which don nated discussion in Mr. Shaar's report. wish to touch briefly on a few of these pro lem areas.

1. Survival suits on the market today have the following deficiencies:
- Self-righting of the survival suits has not been incorporated into the design of most suits available on the market today.
- Better corrosion resistant and maintenance-free zippers for the suits must be developed.
- Better material and seam strength should be considered and used in the future, as these suits tend to develop defects in distress conditions.
- Universal sized suits are often too large for small persons who may disappear in the suit when jumping in the water. Face seals on the suits are not yet satisfactory.
- All regulatory bodies governing offshore areas should have their own means of production control, despite what is being used by other agencies.

2. The life rafts available on the market have the following deficiencies:

- Water and food rations on the rafts are inadequate, and are only provided for very short term survival.
- Life rafts are not equipped with homing or communications devices which would assist would-be rescuers in locating the raft during adverse conditions.
- The traditional means of egressing to the life rafts, knotted ropes and rope ladders, are very unstable and will likely result in the premature falling of crew members into the water with resultant injury.
- Sea anchors provided on the rafts, which are used for drift and positive stability, are inadequate in many sea states.

3. Finally, training of personnel in the use of emergency equipment in various emergency situations is presently inadequate. This lack of knowledge has been at least partially attributable in personnel losses in several offshore accidents.

Training, as well as improved equipment, may lessen the personnel losses in emergency egress situations. However, it is very important to note that time to escape may be the most important factor of all.

Summary of General Discussion Following Paper F

Mr. Per Klem (Ship Research Institute of Norway) clarified his Institute's role in the development of lifeboat design by saying that the Institute is independent of the lifeboat industry, and first developed a free fall lifeboat in 1973 in cooperation with Harding. He said that the free fall concept was first conceived in 1897 and the system which is now installed on the *Dyvi Delta* is based on that initial design with only engineering changes added. The Institute is currently seeking funding to conduct further research into the free fall principle in order to reduce cost, weight, and mechanical complexity in the application of the system to MODUs.

Mr. Klem agreed with Mr. Shaar's approach of retrofitting existing davit-launched systems to make them more successful, but he doubted that the davit system has any advantages over the free fall system and said that its inherent dependence on complicated mechanical devices leads to numerous disadvantages. Mr. Klem, however, agreed that self-bailing and self-righting are important aspects in the problem of the recovery of personnel. He also agreed that full scale testing in stormy seas is desirable, but cited several difficulties: of having all instruments and equipment ready when a storm is forecast; of accommodating the extra personnel during the test; of compensating for the dispensed lifeboat until it is recovered and re-installed. Another difficulty is the fact that free fall boats can only be tested a few times at full scale without incurring damage. He emphasized that the free fall tests to date have not resulted in any major injuries, whereas conventional lifeboats have been shown to cause injuries even during training sessions. Mr. Klem regretted that no mechanism seems to exist to encourage cooperation between industry and government in carrying out the research necessary to develop improved systems.

Mr. Klem commented that while survival suits as they exist today have many unresolved problems, they have saved many lives and should therefore not be discouraged. Mr. R.L. Markle (U.S. Coast Guard) also commented that the self-righting feature of survival suits is over-rated and that it is better for the survivor to practise breath control. Mr. R. Fodchuk (Shell Canada) agreed that self-righting in immersion suits is over-rated and that not all suits professing to have that feature actually do self-right although it is easy to do so with some practice. He said that industry has initiated a cooperative effort with the Canadian Standards Association to develop better suits as part of the total escape system.

Mr. E. Dudgeon (NRC) said that the approach of the Commission in its Part One Report, that not all of the crew of a MODU can or should be equally trained in the use of evacuation systems, is reasonable. Therefore, he advocated increased dependence on support vessels with properly trained crews. This view is supported by a system under development in the U.K. which evacuates a MODU crew by transferring its members, by means of a cable-car-type system, to a support vessel with the aid of a highly trained rescue crew on that vessel.

Dr. C. Brooks (DND Maritime Command Headquarters) felt it is not unreasonable to provide everyone who intends to go offshore with a basic briefing on survival, a tour of the rig, and also some experience in water immersion. Vice-Admiral A.J. Fulton (CAF, retired) agreed that good training in all aspects is highly essential. He doubted the feasibility of transferring personnel from MODUs to support vessels via the cable system and cited the Navy's experience with it as demonstrating that relatively sophisticated equipment with a large number of highly trained people is required to operate it successfully. Mr. Markle agreed that this transfer sytem does not have much potential for the offshore and that it is better for a rig to be self-sufficient.

Mr. J. Gow (Mobil Oil Canada) informed participants that all workers going offshore in Eastern Canada are given a one-week minimum survival training course sponsored by both industry and government. Mr. J. Turton (Survival Sytems Ltd.) briefly described the role of the Basic Offshore Training program and said that, in Nova Scotia, over 1300 have already been trained. In Newfoundland, workers are being trained under a similar program called Basic Offshore Survival Training. He said that industry has taken this initiative and is constantly re-developing and re-assessing the course contents. Mr. R. Fodchuck reiterated the industry's interest in training, and said that the courses include water immersion, both in pools, and in the open sea, with the use of survival suits.

Mr. Gow questioned the installation of survival craft on the upper decks of MODUs, since he viewed access to escape systems as part of the problem. He also pointed out that more responsibility for improved survival craft should be placed on the marine industry rather than the oil industry.

Mr. C. Shaar (SeaTek Corp.) pointed out that the regulatory system and the competitive market in which the lifeboat manufacturers deal do not encourage them to devote a great deal of research time and effort into developing a product which exceeds minimum regulatory requirements. Mr. Fodchuk said that their lack of entrepreneurship and initiative has frustrated the oil industry which looks to them for a solution to the escape problem. Mr. Shaar advocated the setting up of a mechanism which would encourage research and development, even if aimed at improving the free fall system which is the only major development currently being investigated. Full scale tests of the free fall lifeboat should be undertaken, but not to the exclusion of improvements to conventional lifeboat systems that are also practical from an engineering viewpoint.

Mr. Turton asserted that maintainability of lifeboats is an important aspect which is too often overlooked. He pointed to the problem of quality control during the manufacturing process and suggested that the regulatory bodies are not adequately ensuring that lifeboats are either properly produced or consistently maintained. He cited examples of inadequate seat belt attachments, difficult start-up of engines, inadequate sea anchors, and faulty non-skid materials on floors and decks. Mr. D.J. Riffe (Gulf Oil Corp.) admitted that they have experienced deficiencies, many of them due to improper maintainence, in areas of the world where they operate. Mr. Turton also thought that regulators had the responsibility to ensure that escape equipment purchased in one area of the world is suitable for the area where the drilling is to take place. Mr. J.J.S. Daniel (Hollobone, Hibbert) thought it reasonable to set operating criteria for lifeboats in relation to the conditions found in the various parts of the world where drilling takes place and then to design an escape system most suited to those conditions.

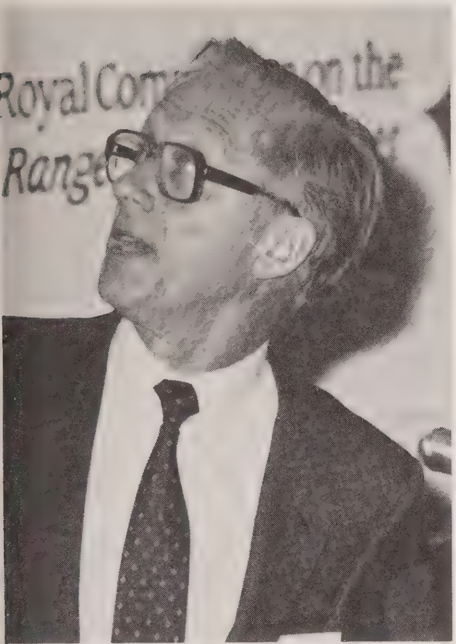
Mr. Shaar felt that too much responsibility for the regulatory agencies was being suggested, as they are not sufficiently staffed to exercise such rigid control over the manufacture, sale, installation, and maintenance of lifeboat systems. Mr. Markle said that U.S. Coast Guard regulations do require quality control during the manufacture of lifeboats, but that such control is difficult to enforce without destroying completed equipment. Nevertheless, Mr. Turton stressed that current manufacturing inspection procedures leave a lot to be desired.

ınd result in too much faulty equipment inding its way to the field.

Mr. I. Manum (Norwegian Maritime Direc- orate) pointed out that, while further levelopment is indeed necessary and should be encouraged, accident statistics lo show that the present design of covered feboats has proven effective in saving many lives. He referred to the *Alexander (ielland* and *Vinland* incidents, and said that on the *Vinland* particularly, the lifeboats are nstalled so that during launching they move away from the rig very early. Mr. Markle re- emphasized the need for launching systems which allow lifeboats to be deployed so that hey remain intact, since it is only in the ntact condition that they can be effective. He preferred the development of an opera- ionally and mechanically simple system which would lower the operation perform- ınce demand and thus decrease training equirements.

Mr. Markle commented that while life rafts ıre not a primary source of abandonment, new stability systems are being developed o increase their effectiveness in heavy veather and they should therefore not be gnored.

Session Chairman Dr. A.J. Mooradian vrapped up the discussion by referring to he need for performance criteria as a focal point in the development of adequate escape systems. He thought that, in view of he cooperative atmosphere evident among he participants, it could be achieved.



Dr. E. Klippenberg
Director
Norwegian Defence Research Institute

Dr. Klippenberg has been with the Norwegian Defence Research Establishment for the last 30 years, working in his specialty of operations research. This period has included a four year term as Chief, Operational Research Division, SHAPE Air Defence Technical Centre, The Hague. Dr. Klippenberg is current Director of the Norwegian Defence Research Establishment.

PAPER G

An Operations Research View of a Rescue System for Effective Response to Emergencies in a Cold Ocean Environment

INTRODUCTION

The purpose of this paper is to examine the rescue system as one main part of the overall program affecting safety offshore eastern Canada. For the purpose of this paper the rescue system is defined to include those elements concerned with the rescue process from tasking of available search and rescue resources to mission completion.

The characteristics of an effective rescue system are, however, very much a function of the nature of the other main parts of the overall program to prevent loss of life and injuries in offshore activities. For the purpose of the discussion in this paper, those other main parts are emergency prevention, the alerting process including decisions and tasking orders to the rescue system, and measures to insure the safe escape and survival of the victims of the emergency up to the time when the rescue units are on the scene. As the total resources available for safety measures will not be unlimited, an optimum overall system will require careful trade offs between its main parts. An examination of the rescue system will therefore have to take place in relation to the other main parts of the total system.

It is not the purpose of this paper to discuss and promote a specific rescue system for emergencies in the cold ocean environment offshore eastern Canada. Neither the necessary information nor the efforts required to do a proper analysis have been available, and Canadian resources would of course be much better qualified and placed to do that. Rather the aim is to examine the main considerations which should be taken into account in the analysis of the present rescue system and its possible enhancements to provide an acceptable system. In so doing I will not bring forward anything really new or startling. A sound and appropriate approach to the analysis and design of a search and rescue system is discussed in the Canadian Report on *Evaluation of Search and Rescue* published under the authority of the Cabinet Committee on Foreign and Defence Policy in 1982, the "Cross Report". Several of the reports prepared for the Royal Commission appear to discuss other important aspects of the system. It is my hope, however, that I have been able to put the main considerations into the proper overall context and demonstrate how they interact and influence the overall performance of the system. To stay within the allotted time and at the risk of appearing superficial, I have had to leave out of the discussion several factors and issues which have to be taken into account in the planning of the future rescue system.

The logical point of departure for examination of systems as complex as the search and rescue system is to attempt to establish the objectives of the system and the criteria against which the effectiveness of the system in meeting its objectives can be measured or at least assessed. Secondly, the paper briefly reviews the types of scenarios in which the system may be called upon to perform its functions, and the chain of events which may characterize such emergency scenarios. Following a brief recollection of the main characteristics of the onsite escape and survival system and of the alerting and decision making process up to tasking of the rescue elements, the paper then examines the various elements of the rescue system, their characteristics and their integration into an effective rescue system.

OBJECTIVES AND CRITERIA

The objective of the Canadian national SAR programme as recommended by the "Cross Report" could apply to any soundly based safety programme for offshore activities. The recommendation reads:

> To prevent loss of life and injury through search and rescue alerting, responding and aiding activities which use public and private resources; and by ensuring priority to aviation and marine safety measures focused on owners and operators most commonly involved in SAR incidents.

Taken literally, however, this objective is obviously not achievable. No practical safety programme will be able to prevent loss of life and injury with 100% assurance. As for most other complex man/machine systems the relationship between the degree to which the system meets its broadly formulated design objective and the total system cost (investments plus recurring costs) is of the well known S-type illustrated in Figure 1. For other systems not concerned with issues as sensitive as the rescue or loss of human lives it is usually not too difficult for responsible authorities to decide on an acceptable compromise between system performance and total system cost. Often the knee of the S-curve is taken as a good compromise. Above this point the marginal return in terms of increased system performance per additional dollar system cost, is diminishing. For a safety programme the decision on how much is enough is a much more contentious

issue, and will, probably in most cases, be a result of considerations of acceptable total programme costs rather than an explicit decision on programme performance resulting in a certain programme cost.

In the preceding section the rescue system was defined to include those elements which respond to a tasking order and carry out search and rescue. Its performance as a function of total resources allocated to this subsystem describes an S-curve similar to that of the overall programme. However, its shape and location along the cost axis depend very much on the characteristics of each of the other major subprogrammes, namely:

- Emergency prevention
- Alerting, decision making and tasking of rescue resources
- Escape and survival in local area

Emergency prevention measures such as improved design of MODUs and vessels and better trained crews will of course reduce the chance of emergencies occurring. Perhaps of more importance from a rescue system point of view, is the extent to which such measures would make early detection of a developing emergency more likely and slow down the rate at which a beginning emergency develops into a crisis, immediately threatening lives or forcing abandonment of the MODU or vessel, Figure 2. That would provide more time for rescue operations and reduce the cost-driving time pressure on the rescue system.

Similarly, measures to ensure the safe and orderly escape of personnel from the MODU or vessel when forced to abandon, and measures to extend the critical survival time after abandonment would further increase the time available for rescue operations and reduce the pressure on this system, Figure 3.

From a rescue subsystem point of view, some of the total time (B-D in Figure 3) available for rescue is, however, eaten up by the command and control process which includes alerting the rescue control system, decision making in this system, and tasking of rescue vessels and aircraft. Reduction of this time through appropriate delegation of responsibility and dependable communications further increases the time available to the rescue system to complete its mission, Figure 4.

Strictly from a rescue system point of view all efforts to improve the other subsystems in the safety programme are highly desirable because this would reduce the strains on the rescue system. From an overall cost/effectiveness point of view efforts in the four subprogramme areas should of course be balanced in the sense that each additional dollar allocated to any one of the subprogrammes should produce the same improvement in overall system performance.

Because of the criticalness of the time factor and the fact that time available for rescue is determined by the other subprogrammes a useful way of expressing the performance of the rescue system would be the rescued fraction of persons involved in the emergency, as a function of time. The shape of the curve describing the fraction rescued as a function of time will of course vary from one type of scenario to another. In serious emergencies and difficult rescue conditions the shape of the curve in the first and very rough approximation will also be S-shaped, Figure 5. A closer examination will undoubtedly reveal that its shape is more complicated and influenced by the rescue characteristics of the subelements making up the rescue system. But the fact remains that some time is required before the rescue platforms arrive in the area and the rescue process can begin. As the rescue process proceeds, the curve raises with a certain slope; the rescue process will, however, take time, and as time passes the victims may be spread over an increasing area. Additional search to locate the victims may therefore slow down the rescue process and the slope of the curve decreases.

As stated above, the relationship between time and fraction rescued will of course also depend on the type of emergency and its location. A given rescue system will perform differently in an emergency involving a MODU with a large number of persons and an emergency involving a supply vessel. For an assessment of a rescue system it will therefore be necessary to construct the time versus fraction rescued relationship for a not too large number of different emergency scenarios. To this end computer simulation of the rescue system and its operation will be a useful tool. If the system does not meet required performance levels in one or more of scenarios, modifications to the rescue system may be tried out through simulation until an acceptable system is found.

EMERGENCY SCENARIOS

The report on Search and Rescue, contracted by the Royal Commission, suggests five types of incidents or emergencies for consideration in an assessment of the rescue system, Table 1. This set of incidents is probably a good and useful representation of the spectrum of emergency types under which the rescue system may be called upon to perform its mission. Considering future oil production it is, however, possible that stationary production platforms may be used in some of the areas offshore eastern Canada. For reasons of economy they could be quite large and the number of peopl aboard, particularly during the installatio and development phase, could be a fe hundred rather than the 50 to 100 on MODU. By adjusting the number of peopl involved the MODU cases in Table 1 coul also represent stationary production pla form emergencies.

The planned evacuation of a MODU cou occur as a result of the forecast of seve storm conditions, encroachment of ice other factors. The evacuation with limite warning could occur if planned evacuation not successful, or due to undetecte encroachment of ice, loss of stability other factors. A major structural failure, blow-out with fire or some other cata trophic effect could require immedia evacuation.

The supply vessel faces the same hazar at sea as other ships. But because of i function there are additional problems suc as transfer of heavy cargo at sea, operatic very close to the MODU, and in the shiftir of deck cargo and ballasting while at sea.

The hazards associated with helicopte mainly revolve around a helicopter cras while landing on a MODU or vessel ar crash or ditching of a helicopter while transit. A crash or ditching enroute w probably result in the helicopter overturnir before the survivors can be evacuated.

The incidents may occur under any weat er situation, day or night. The meager stati tics available on the other side of the Atla tic Ocean, about the weather offsho eastern Canada, indicates that limited vis bility and ceiling could prevent helicopt operations from about 10 to perhaps 1C hours of every month, depending on loc tion and month of the year. Icing conditio will also prevent helicopter operations ar may last for a number of hours when occurs. Weather necessitates helicopter IF operations for about 70% of the year. Th considerably reduces the effective range helicopters.

Sea ice and icebergs are also part of th scenario, and the low temperature of th sea water makes rescue of persons in wat and in liferafts highly time critical. Th "Cross Report" states survival times f unprotected persons in the water from 1 minutes to one hour during nine months the year. Injuries can reduce this time whi good abandonment suits can perhaps mul ply these times by a factor of ten, while f current helicopter survival suits the mul plication factor is about two. Finally, th emergencies may occur anywhere in th vast areas offshore eastern Canada whe the offshore industry is active, Figure 6.

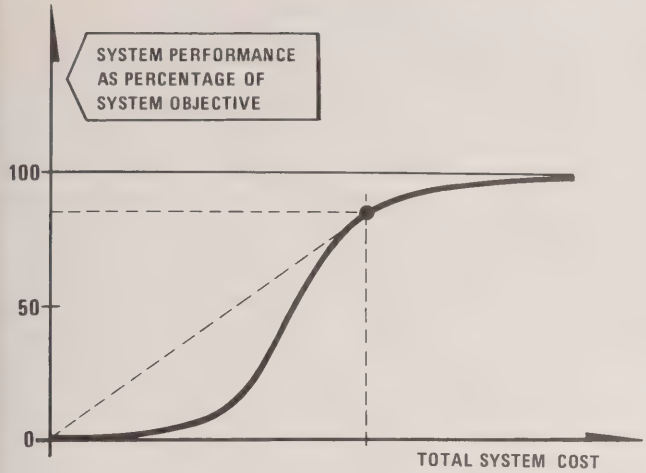


FIGURE 1 Relationship between system performance and total system cost

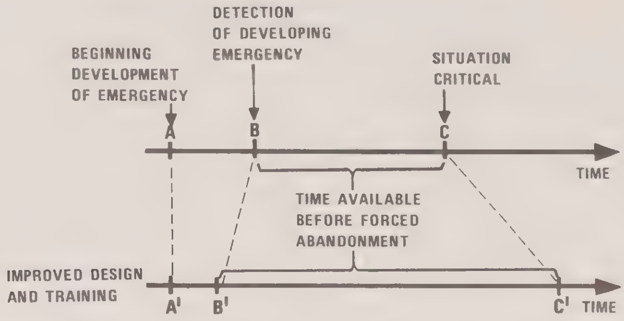


FIGURE 2 Effect of improved design and training on rescue system

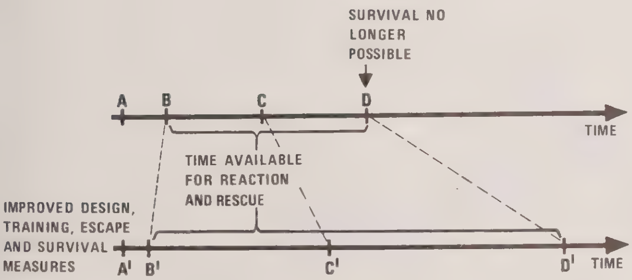


FIGURE 3 Effect of improved design, training, escape and survival measures on rescue system

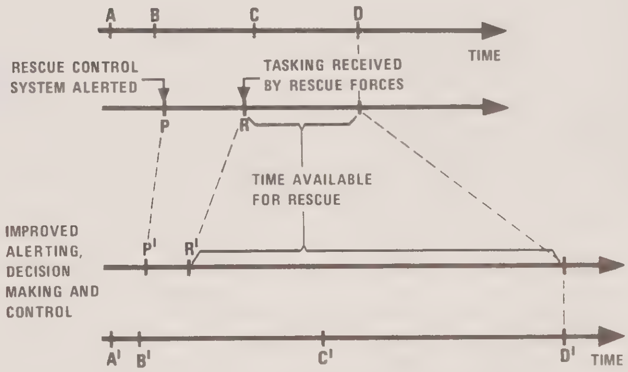


FIGURE 4 Effect of improved alerting, control and tasking on rescue system

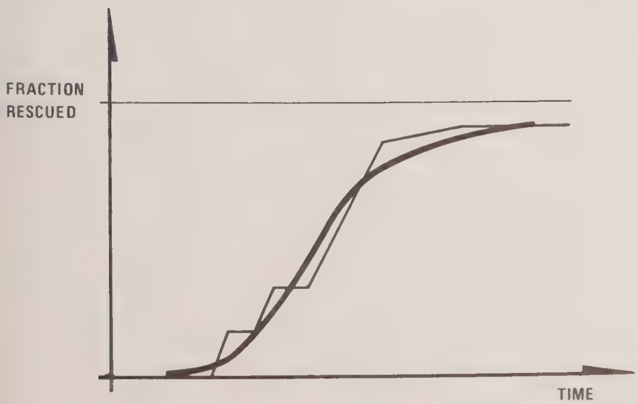


FIGURE 5 Criterion of effectiveness for rescue system

	PERSONS INVOLVED	TIME FOR EVACUATION	REMARKS
MODU – PLANNED EVACUATION	50–100	12–18 hrs	DRY TRANSFER TO OTHER VESSEL OR LIFEBOAT
MODU – EVACUATION WITH LIMITED WARNING	50–100	1–2 hrs	AS ABOVE, POS SOME IN LIFERAFTS ON WATER, WEARING SURVIVAL SUITS
MODU – IMMEDIATE EVACUATION	50–100	Few mins	POS LARGE NO OF PEOPLE IN WATER W AND W/O SURVIVAL SUITS
SUPPLY VESSEL	12–16	Few mins – 1 hr	MOST IN LIFEBOATS AND LIFERAFTS, POS SOME IN WATER PROB ALL IN SURVIVAL SUITS
HELICOPTER	UP TO 20	–	MAJORITY IN WATER W/IMMERSION SUITS

TABLE 1 Types of incidents

THE RESCUE SYSTEM

Description of system elements

For rescue operations of the sort which may be required in connection with industrial activity offshore eastern Canada, two types of rescue platforms seem to be of primary importance, vessels, and helicopters. The primary role of fixed wing aircraft in such hostile environments would seem to be limited to searching, in those cases where the location of the emergency or its victims is uncertain or unknown.

From a rescue point of view helicopters and vessels have quite different characteristics. A brief examination of the time line for helicopter and vessel rescue operations may therefore be in place, Figure 7. In this discussion it is not the intention to examine the difference between national SAR resources and industrial or commercial resources which could be used for search and rescue, but rather to emphasize the generic characteristics of the two primary types of rescue platforms.

Helicopters

The reaction time for a helicopter on the ground or on an offshore helicopter deck is the time from receipt of tasking order (R and R[1] as shown in Figure 4) to take-off. This covers the time required to assemble and brief the crew about the emergency, develop a flight plan, and refuel the helicopter. For national Canadian SAR helicopters the maximum reaction time is one-half hour during working hours and two hours at other times. The effective reaction time for an airborne helicopter would depend upon fuel status and the number of passengers or load carried. Industrial helicopters would normally carry a fairly full load which would have to be disembarked on shore, on a MODU or a ship with a helicopter deck before diversion to a rescue mission.

Refueling might also be required. The same considerations would probably apply to national SAR helicopters except perhaps when on a training mission. A helicopter located on a MODU would probably have the shortest reaction time, perhaps 10 to 15 minutes. In summary, the reaction time could vary from 10 minutes to 2 to 4 hours, depending on the circumstances.

Normally the transit speed of helicopters is in the range of 115 to 135 knots or nautical miles per hour. The distance from Sydney to the Sable Island area and from St John's to Hibernia is about 160 nmi and would take about one and one-half hours, Figures 8 and 9 (from the Rescue Report). To reach the more remote areas under IFR conditions would take two and one-half to three hours because refueling, for example at Hibernia, would be required. With head-winds the transit times could be considerably longer. In the areas further north the distance from the offshore activity to the nearest shore base could be greater and the time correspondingly longer.

Assuming that transport helicopters enroute report their position every 30 nmi, that supply ships and other industrial vessels report their positions every four hours or at least their time and point of departure as well as destination, and that the rescue control system maintains reasonably up-to-date records, the position of an emergency should be known with sufficient accuracy for a helicopter to locate the emergency site without much loss of time. This assumes radio transmission from the ship or MODU in distress or from free-floating emergency radio transmitters permitting the helicopter to use its direction-finding equipment to home in on the site.

If, however, the ship or MODU had to be abandoned before the arrival of the helicopter, the personnel would under fortunate circumstances be in covered life-boats and, under less fortunate circumstances, in liferafts or in the water.

Following a helicopter crash or ditching the survivors would also be in the water, possibly in liferafts. Depending on the time since abandonment, wind and sea currents, life-boats and survivors in the water could have drifted off a considerable distance. A two or three nautical mile drift in one hour is not unlikely. Even so the location of covered life-boats with emergency radio beacons should represent no great problem. Persons in the water could be spread over a fairly big area and, except under favourable conditions with good light and visibility, the search could take considerable time. Already at 15 knot winds and three to four foot swell heights the effective detection range for persons in water under daylight conditions may be as little as a few hundred feet. Survival suits should therefore be made of a strongly fluorescent material giving good contrast to water and be equipped with lights. U.S. Coast Guard trials seem to indicate that strobe survival suit lights could increase the effective detection range to several nmi and dramatically increase the chance of locating persons in the water under conditions of reasonable visibility. For conditions with less visibility the development of some sort of survival suit radio transponder seems highly desirable.

Having located the object of the search, helicopters would require only a few minutes to land on a helicopter deck or get into the correct hover position and deploy rescue gear. A helicopter able to land on a helicopter deck would only need minutes to embark personnel, but loading of persor on stretchers would take more time.

The most reliable way of rescuing persor in the water and on liferafts under most cor ditions seems to be for a rescue man to b winched down from the helicopter to assi the survivors into a horse-collar for hoistir up, one by one. With a good hydraul winch capable of continuous operation ar no significant spread of the persons in th water, rescuing of 15 persons could take 3 to 40 minutes. If, however, the persons water are dispersed and search is necessa to find single survivors, considerably mo time would be required. The evacuatic transit time would of course depend on th distance to the nearest MODU, ship shore base for disembarkation.

The characteristics of a well equipped he copter in rescue operations may for the pu pose of this discussion be summed up wi Figures 8, 9 and 10. Figures 8 and 9 sho the maximum coverage of two typical of shore helicopters under IFR conditior which in this area prevail about 70% of th time. The coverage assumes only 3 minutes search and assistance time in th emergency area. Helicopter operations w not be possible, mainly due to low ceilir and visibility, from 10 to 100 hours p month, depending on location and time the year. Depending on the location of th emergency relative to the helicopter ba and assuming a nearly perfect alerting, dec sion making and tasking system, it cou take up to three to five hours for a lan based helicopter to reach the site of th emergency, Figure 10. A helicopter on helicopter deck or in transit in the area offshore activity could in many cases rea the emergency site much sooner. Und favourable conditions it could quickly pi up its full, but relatively small load of sur vors. Under less favourable conditions th search and pick-up process could be mu slower and fuel limitations might not gi room for picking up a full load. The tir required before the helicopter could retu to continue the rescue operation wou depend very much on the presence of shi and MODUs with helicopter decks whe the survivors could disembark and the he copter be refueled. The capacity of the he copter, from 12 to about 20 depending type, matches well the needs in supply ve sel incidents. In a helicopter incident th capacity of a single rescue helicopter cou be on the low side. In a MODU emergenc the capacity of a single helicopter is likely be inadequate except for planned evacu tion with many hours available to comple the operation and with another MODU ship with helicopter deck in the vicinity receive the personnel.

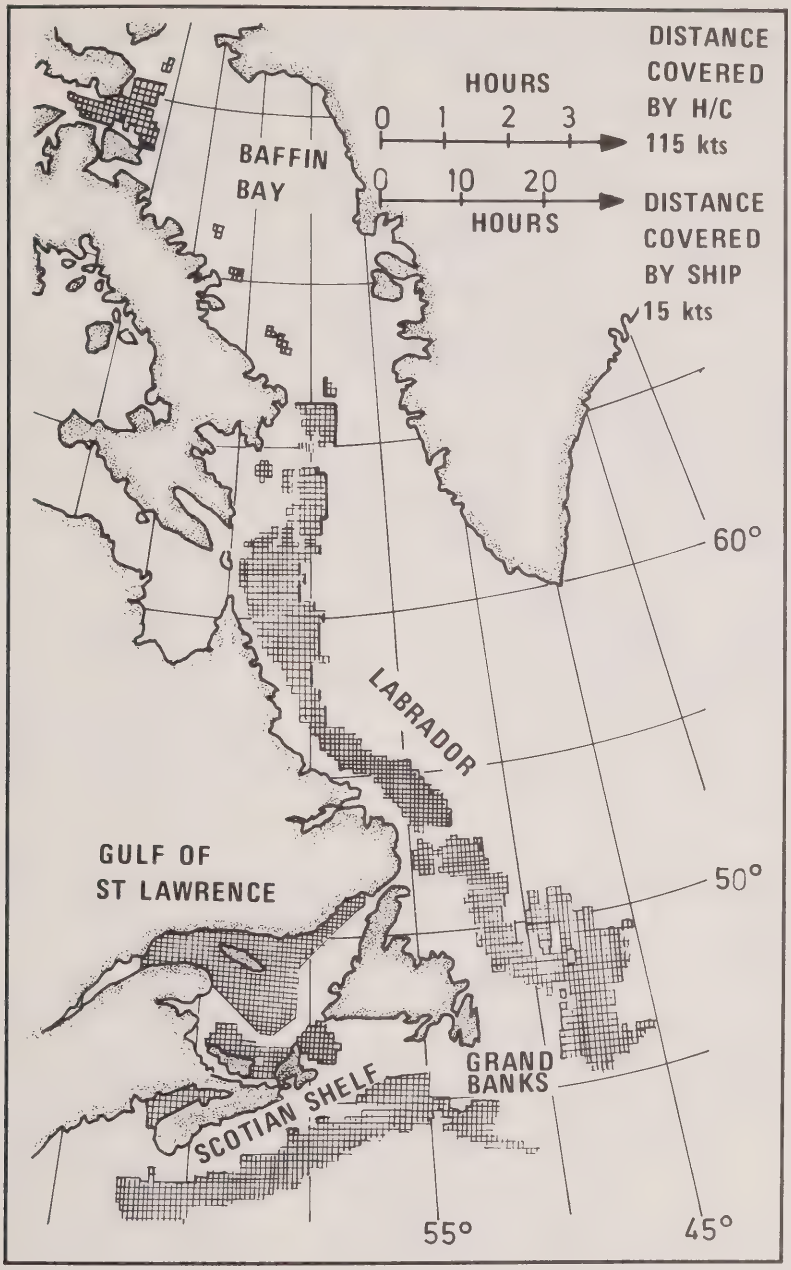


FIGURE 6 Oil and gas exploration lease areas

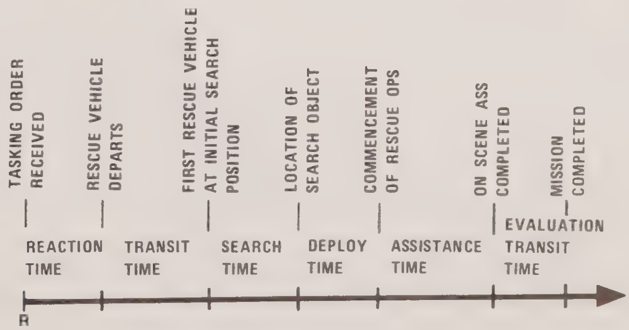


FIGURE 7 Time-line for rescue operation

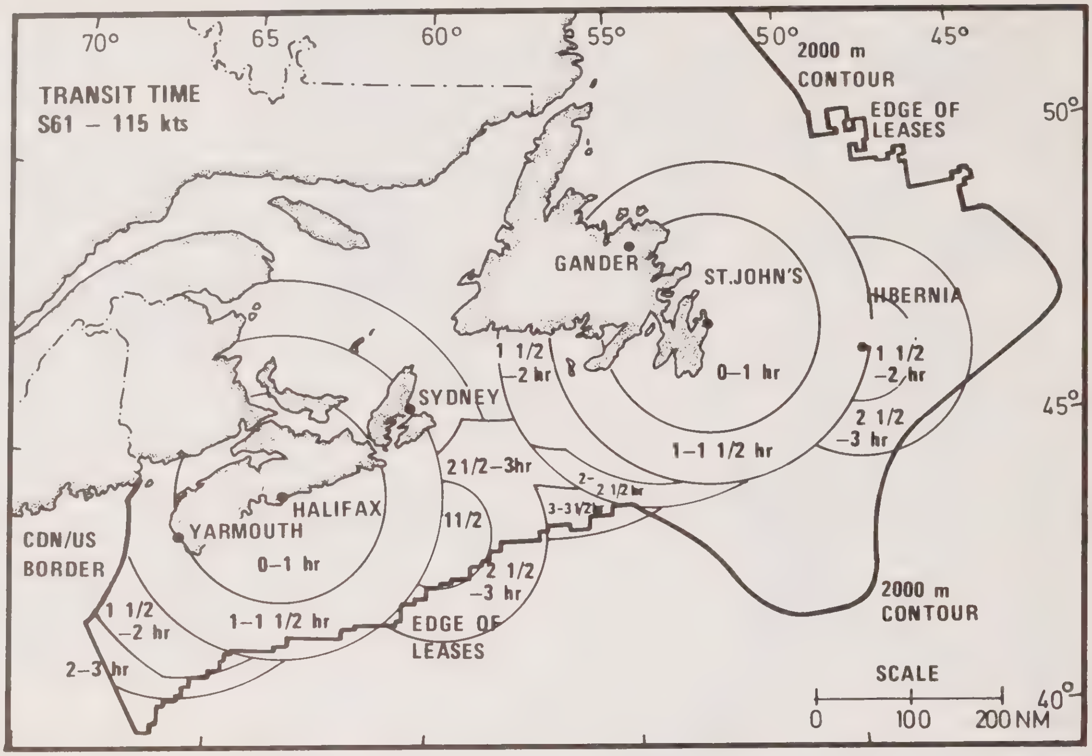


FIGURE 8 Transit time: S61 – 115 kts

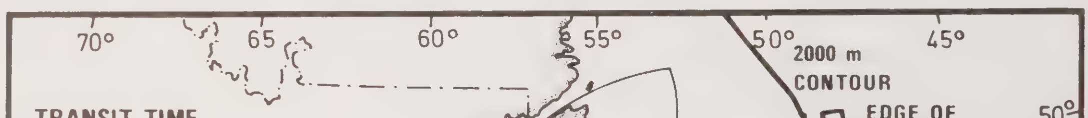


FIGURE 9 Transit time: Super Puma – 135 kts

Vessels

Vessels as rescue platforms are primarily characterized by their low transit speeds and their capacity to accommodate a large number of survivors once in the emergency area. The effective speed of the majority of vessels operating in the area is between 10 and 15 knots. In reasonable weather the transit from St. John's to Hibernia could take from 11 to 16 hours. The additional reaction time could vary between 30 minutes and a few hours. Ships in port would therefore not be very useful for rescue operations unless the emergency site was not too far from the port or the emergency was developing slowly.

A ship under way, on the other hand, would have a very short reaction time and the transit time for ships in the area of the offshore activity would also be short. In the case of a MODU emergency a suitable stand-by vessel located within the required one nautical mile could within minutes manoeuvre into a favourable position for assisting people abandoning the MODU. Under favourable conditions this could take the form of dry transfer with one of the cranes on the MODU. Under less favourable conditions the stand-by vessel would assist lifeboats and rescue people on liferafts and in the water. The stand-by vessel would launch one or two fast rescue craft to increase the rate at which people in liferafts and in water could be recovered and brought aboard the stand-by vessel. Such fast rescue boats can operate under most conditions and are very fast (25 knots). Normally they can be launched within minutes and very quickly reach located liferafts and persons in the water. With many persons in the water, the rescue operation will nevertheless take time and persons and liferafts would drift off and become spread over an increasing area. Except with a moderate sea and with good light and visibility conditions, this could increase significantly the time required to locate survivors and slow down the rescue process. Survival suits of fluorescent material with reflectors, flash or strobe survival suit lights, and preferably some sort of radio transponder could greatly accelerate the process. Regrettably, it has not been possible to locate any data which could help quantify the rescue process with vessels and FRC. Under moderate sea conditions and with the survivors not too widely spread, a FRC and a vessel could probably get people out of the water and liferafts at a rate not much slower than a helicopter. In a heavy sea, however, both vessel and FRC would probably find it more difficult to locate survivors because their means of search have less height above the sea.

In the case of a supply vessel or helicopter emergency not too far from a supply or stand-by vessel, such a vessel could be under way a few minutes after receipt of a tasking order. In one and one-half hours the vessel could transit about 20 nmi and its fast rescue craft about 35 nmi. Within such distances vessels could reach the emergency site about as fast as helicopters available on a MODU in the area. Assuming moderate delays in the alerting and tasking system and activated free-floating emergency radio beacons, the search for the emergency site should not take much time. But the search for liferafts and persons in the water could pose problems as discussed above.

The rescue characteristics of a well equipped stand-by or supply vessel may be summed up with Figures 11 and 12. Figure 12 shows the area within which a stand-by vessel at Hibernia and its FRC can reach an emergency in less than one and one-half hours. The Figure also shows the corresponding coverage of a supply ship under way between St John's and Hibernia. In a MODU emergency the stand-by vessel and its FRC could quickly initiate assistance and rescue, and under reasonably good conditions take people aboard at rates possibly not too different from the rate at which a hovering helicopter could hoist people aboard. Under more difficult conditions with survivors spread over an increasing area the search would, as for helicopters, slow down the rescue process significantly.

The vessel has, however, a much higher capacity than a helicopter and should be able to take aboard the whole crew from a MODU. Contrary to the helicopter, restricted visibility and ceiling represent no absolute limitation on its operation. Very limited visibility and very heavy weather would of course slow down rescue operations.

Rescue system consideration

Having briefly examined the major elements of the rescue system and their characteristics, some of the main considerations pertaining to the rescue system will be discussed.

No emergency prevention, safety precautions or escape measures will ever provide full assurance against a number of people ending up in a liferaft or in the water following an emergency. In the hostile environment offshore eastern Canada the survival time without additional protection would be so short that no rescue system could be expected to have more than a very modest chance of success. Although there seems still to be room for desirable improvements in survival suits, the issuing of such suits to everyone involved in offshore activity would dramatically change the situation and bring a reasonably effective rescue system within reach. At a cost of about $450 (Canadian) per suit, the cost for the full complement of a MODU would be less than $50,000, which is less than half the daily rate for a second generation MODU.

Considering the distances from shore bases to the areas of offshore drilling and the criticalness of time in many of the conceivable emergency situations, a credible rescue system seems to have to be based to a large extent on rescue platforms available in the local area.

In light of the number of people involved in a MODU or a production platform emergency and the fact that weather prevents helicopter operations some 10 to 100 hours each month, a properly equipped and trained stand-by vessel at each MODU or platform would seem to be an essential first element in a rescue system. The effectiveness of the stand-by vessel would depend very much upon its manoeuvrability and stability, good communications and navigation aids, means for locating liferafts and persons in water, proper free-board and a well designed and equipped rescue area midships, at least one FRC and the best means for launch and recovery of the FRC, and a sufficiently large open area for landing people from a helicopter or a MODU crane. The daily rate for such a vessel in the Norwegian Sea runs about $20,000, while the corresponding daily rate for a second generation MODU is about $100,000.

Another element of primary importance would seem to be the equipping and training of supply ships and their crews to deal primarily with emergencies involving another vessel or a helicopter. If helicopters and supply ships where following roughly the same transit lanes, such equipped and trained supply ships would represent a significant rescue capability in areas which other rescue vehicles may require more time to reach. Ideally the supply vessel should have the same rescue fit including at least one FRC as the stand-by vessels, but of course not the same accommodation capacity. The additional cost of operating a so equipped and trained supply vessel would not be much higher than the normal rates for a well equipped supply vessel ($25,000 to $35,000 per day.)

The rescue characteristics for helicopters are in many ways complementary to those of vessels. They are well suited to lift people off MODUs and ships even under very difficult conditions; with a rescue man and hoist they are able to hoist people from liferafts and out of water under very severe conditions; within unrefueled range they transit faster, and they are also more effective in search for liferafts and persons in water. But the number of people they can carry is somewhat limited. Although to some

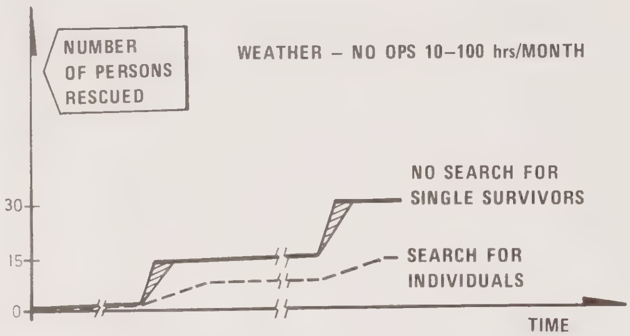


FIGURE 10 Helicopter rescue characteristic

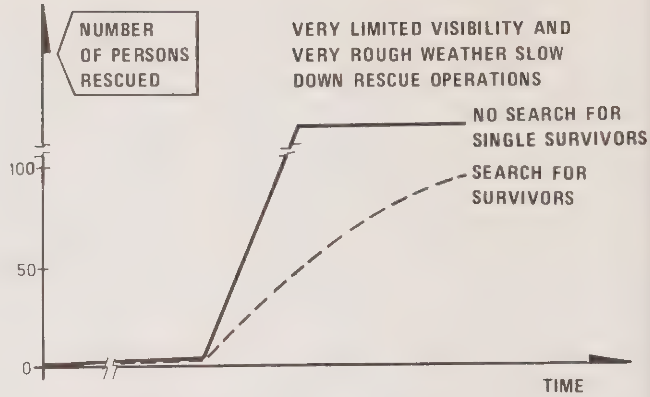


FIGURE 11 Vessel rescue characteristic

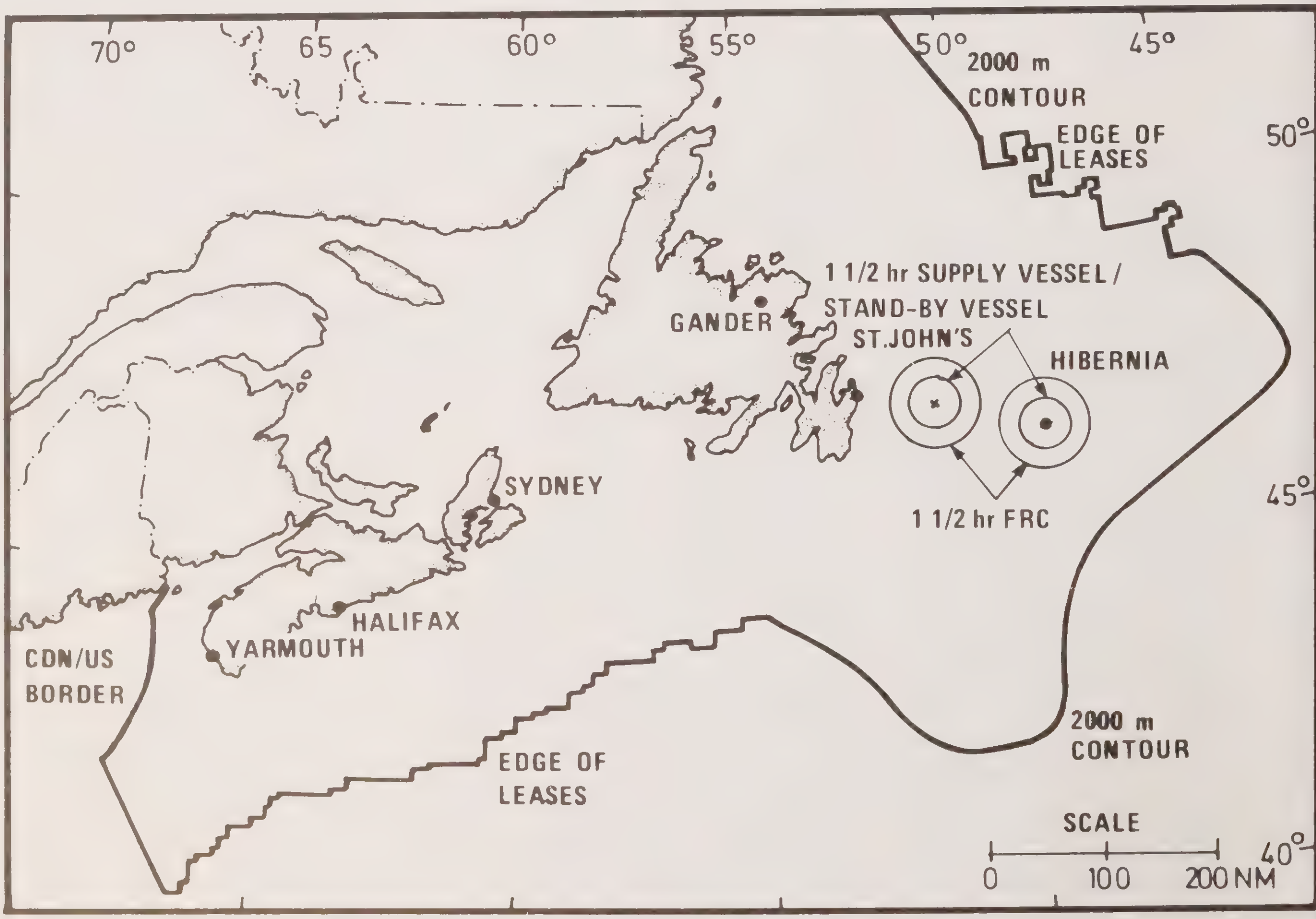


FIGURE 12 Transit time for stand-by vessel/supply vessel and fast rescue craft

xtent weather limited, they appear to be ssential elements in a balanced rescue sys- em.

It seems, however, highly desirable to have elicopters in the rescue role with less esponse time than shore based rescue heli- opters. With the increasing activity offshore astern Canada this could probably to an icreasing extent be achieved by adopting ie current Norwegian Sea practice of div- rting transport helicopters to rescue mis- ons when the need arises. The hoists for ie transport helicopters are stored on the iore base and aboard the MODUs and at ast one member of each MODU crew is ained as a rescue man and ready to join ie helicopter crew. In this way industry heli- opters may quickly and at a modest cost e converted to rescue helicopters. Agree- ients between the operators in the area bout standardization of rescue equipment nd training and about coordination and iutual support in emergencies would ppear to offer the potential for a cost effec- ve and reasonably responsive helicopter ement in the rescue system.

While impressive and capable, the current ational Canadian SAR organization ap- ears not to have adequate capacity to deal ith many of the conceivable offshore emer- encies. The number of rescue vehicles is nited, and they are based to be able to spond also to the many non-offshore inci- ents. From an overall national economy oint of view more rescue capacity at less ost can probably be secured by maximum se of helicopters, vessels, and communica- ons and supporting systems already avail- ole in the offshore industry. Whether the dditional costs for such exploitation of off- iore resources are to be carried by the perators or the state is of course a matter policy and a difficult negotiation.

Although the command and control sys- m has been covered by others, a com- ient on control principles may be in place. ince time is likely to become such a critical ictor in many emergency contingencies, elegation of authority to initiate and exe- ute rescue operations to a MODU or vessel ose to the scene of the emergency would eem highly desirable. This would avoid ommunication, interpretation, and decision iaking delays at higher and more remote vels. Of course, higher levels should be ept as well informed as possible in order to e prepared to take over control if the need ises. As an example, Norway has dele- ated the primary responsibility for rescue perations to the offshore operator compa- es. Their rescue operations are at least ini- ally controlled from a MODU or stand-by essel. If extent or development of the mergency so requires, control is taken over y the onshore company rescue control center. The national SAR organization would normally take over control only if their resources or other non-company resources were required.

It is of course realized that creation of an effective rescue system is more than a question of rational reasoning about the characteristics of the various elements and their most cost effective integration into a system. The objectives and interests of the various governmental departments concerned with offshore activity, of the national SAR organization, and of the offshore operators and their contractors are not necessarily coinciding, and difficult legal, economic, and standardization issues are involved. Nevertheless, an analytical and largely quantitative assessment of the desirable configuration of an effective rescue system would probably be a good point of departure for the planning and negotiations which will eventually lead to the real rescue system.

CONCLUDING REMARKS

In conclusion, the intention has been to discuss the main factors influencing the design of an effective offshore rescue system, and their interrelationships.

While the formulation of acceptable and achievable objectives is a contentious issue, unrealistic goal statements are likely to frustrate efforts to achieve the best rescue system with available resources. The rescue system is only one of several subprogrammes in the overall offshore safety programme. Its performance and the success of the whole safety programme critically depends on the proper matching and balancing of the subprogrammes.

Time is a critical factor in rescue operations and particularly so in the hostile environment offshore Eastern Canada. Good and accessible survival suits for everyone active in the offshore areas appear to be a precondition for an effective rescue system.

Vessels and helicopters have complementary rescue characteristics and both have an important role to play in a balanced rescue system. Because of the geographic distance in the eastern Canadian offshore activity, any but slowly developing emergencies require locally deployed rescue resources. From an overall economy point of view exploitation of industrial vessels and helicopters seems very attractive. Industrial involvement and responsibility for at least the initial phases of rescue operations would facilitate local control and reduce time delays in the control system.

Simulation and quantitative analysis could provide a good basis for the development of a cost effective rescue system for offshore activities. With the reputation of Canadian analysts there can be no doubt that Canada has the skills and resources to undertake such analysis if it so wishes.

[Editor's Note: Much of the material used in Dr. Klippenberg's paper was based on a draft report prepared for the Royal Commission by Vice-Admiral Fulton et al, the final version of that report contains some minor revisions.]

COMMENTARY ON PAPER G

I. Denness
Frontier Drilling
Gulf Canada Resources

Owing to the short time that was available for responding to Mr. Klippenberg's paper, let me say that I am presenting my own views based on my own experience which may not coincide with the views of the East Coast offshore operators.

Because prevention is better than cure, there are probably two main options in preventing the need for a rescue operation: firstly, in order to achieve as near perfect safety as is humanly possible, we would probably have to spend millions of dollars, as is done in the space programs or nuclear industry. Alternatively, we could dispense with the human element on the vessels altogether, as the trend has been in the diving industry where remotely operated vehicles (ROVs) are playing an increasingly major role.

Neither of these two options I suggest are really feasible or even necessary as an immediate or short term remedy. We must step back from the ideal world and revert to the real world where the name of the game is, after all, cost effectiveness, in terms of drilling and finding oil in offshore Canada. We must turn our attention to the practicalities and what can reasonably be done to incorporate an effective rescue system into our offshore operations.

I agree with Mr. Klippenberg that there are three elements to the rescue system:

- Emergency prevention
- Alerting, decision making, and tasking of rescue resources
- Escape and survival in the immediate vicinity

With regard to emergency prevention, I think everyone appreciates the validity of the statement that better trained crews will reduce the chance of emergencies occurring.

With regard to alerting, decision making and tasking of rescue resources, the mechanism now exists for the offshore industry, regulatory agencies, and SAR authorities to communicate both formally and informally at both the senior management level and the technical operator level, and this has led to a far better working relationship and many improvements and advancements have been made. For example:

1. A traffic management system called FLIGHT FOLLOWING which monitors and plots the location of all ships and aircraft associated with offshore operations is in use.
2. Joint exercises in communications and simulated emergencies have been held.
3. Dedicated SAR radio frequencies are in use so that in the event of an emergency both aircraft and vessels are able to communicate effectively.
4. Co-ordinated alert and evacuation proce dures have been written by individual opera tors to cover their specific operation, and when an emergency necessitating an abandonment occurs, there should have already been a planned staged evacuation.

Perhaps it is worth mentioning at this poi that having alerted the rescue resource where are they? And where do they com from? Mr. Klippenberg quotes the 198 "Cross Report" objectives and terms of re erence for the SAR programme: "To pr vent loss of life and injury through SA alerting, responding, and aiding activiti which use public and private resources; a by ensuring priority to aviation and mari safety measures focussed on owners a operators most commonly involved in SA incidents." He then states that the appears to be an inadequate SAR capac to deal with offshore emergencies and would agree with this, even taking into co sideration the existing arrangements whi utilize private assistance. The Canadian o shore industry still turns to DND for mai taining the SAR responsibility even thou there is increasing pressure on the operat to do more. The offshore operators accept their own responsibility in terms emergencies, such as medical evacuatio and search and rescue capability. It industry which is promoting the use of t EMPRA basket as a simple and effecti means of plucking people out of the wat It is the industry's view that the EMPRA ba ket does have distinct advantages over t horse collar in that it does not put the S technician at risk and also it can lift m than one person at a time with the large s basket. Furthermore, industry does not ha time or facilities to train SAR technicians does, however, have the disadvantage t a back-up rescue facility, such as anot MODU or standby vessel, should be close hand so that survivors can be treated.

In the way of short term improvements the SAR capability, I agree with the Resc Study carried out for the Commission wh recommends that contracted SAR helic ters should service the oil industry. On question of financing, I see the upgrading the helicopters and crew training as bein Government responsibility, with indus paying a user fee, when and as required.

In the way of long term improvement would like to see much more empha given to the type of aircraft used for S work; not only must it have all the la

electronic gadgetry for navigation and detection plus increased range and speed, but as Chris Brooks stated, it should be designed so that it is truly amphibious and will not turn over when forced to ditch. Another feature worth considering is the capability of a helicopter to recover either a lifeboat or life raft directly from the sea.

Mr. Klippenberg mentions that Norway has delegated the primary responsibility for rescue operations to the offshore operator. This is a concept I find very interesting, and I wonder if Mr.Klippenberg would explain the rationale for relegating the SAR organization to a secondary role.

With regard to Mr. Klippenberg's third point, escape and survival, it is generally accepted that helicopters are the prime means of evacuation; however, several limitations are imposed which reduce their effectiveness. Therefore, we must turn our attention to an alternate method, the standby vessel. Its great advantage is that it is on location and able to accommodate a large number of survivors. Mr. Klippenberg supports the use of a dedicated standby vessel, and here I would also agree. Purpose built and dedicated standby vessels have numerous advantages over utilizing supply boats or converted trawlers. Their design may then be able to incorporate other safety and operational functions such as:

- Fire fighting
- Anti-pollution measures
- Iceberg towing
- Anchor handling

By having a dedicated standby vessel, I believe the crews would be better trained and equipped, not only to use the existing rescue equipment, but to provide feedback for improvements and new designs in rescue equipment.

The idea of helicopters and supply boats following approximately the same traffic routes is a simple idea, yet as Mr. Klippenberg points out, can provide yet another rescue capability. Mr.Klippenberg has not mentioned evacuation by lifeboats but they too must also be considered a vital part of any rescue system. Several studies have been carried out on the ability to launch an enclosed lifeboat during rough sea conditions. The conclusions reached in these reports would indicate that improvements in launching systems are required. Indeed, the whole aspect of lifeboats, from launching to recovery systems, and also what has up until now been a disregarded subject, survivor comfort, should be the object of R & D programmes and funding. I would like to see not only lifeboat manufacturers and regulatory bodies discussing design features, but also end users and SAR groups. The latter two, I am sure, have ideas which they would like to see incorporated in any totally enclosed lifeboat. For instance:

- Where do stretchers go?
- A top access hatch to allow for SAR winching operations might also be a good idea.
- An adequate supply of sea sickness bags should be included.

Mr. Klippenberg stated that some improvements in immersion suits are required. I agree and am glad to say that at the moment a technical committee under the Canadian Government Standards Board and comprising members from Government (and Dr. Brooks), manufacturers, and end users are currently working on a new standard for helicopter passenger suits and also towards improving the existing standard for abandonment suits.

COMMENTARY ON PAPER G

Dr. G.R. Lindsey
Chief, National Defence Headquarters Operational Research & Analysis Establishment

Rather than discussing the details of Dr. Klippenberg's very useful and interesting paper, which was directed primarily towards the subject of rescue from drilling platforms and their supporting services in cold water, I would like to analyze beyond the subject that he covered, but still stay within the Conference theme of Safety Offshore Eastern Canada. An analysis of search and rescue offshore Canada could take, as its objective, the optimization of the safety of:

1. Drilling platforms on the Atlantic coast;
2. The services supporting the drilling like the supply ships and helicopters which are probably more susceptible to accidents than the big platforms;
3. All commercial maritime activities on the Atlantic coast;
4. All maritime activities including pleasure as well as commerce;
5. All activities in eastern Canada on land as well as the sea which produce a need for search and rescue.

Now the target for this Conference is Safety Offshore Eastern Canada and it may not go as far as my objective number 5. I suggest that it certainly should extend beyond number 1, that is drilling platforms only, and even if we decide to go no further than number 2, that is drilling plus its supporting activities, we will still want to draw on the resources already provided in numbers 3, 4 and 5 by the existing Government Search and Rescue services. We should recognize that the Government SAR system has been built up with its primary concern being number 5, that is, whatever it can do for people who need search and rescue, whether on land or near the coast or far away. Numbers 1 and 2 are rather relatively recent arrivals on the scene.

Now the tragedy of the *Ocean Ranger* was of such a magnitude that we focus our attention on number 1. There is a tendency in all society to concentrate attention on major disasters, even if the total loss of life may be less than that from a number of smaller, lesser newsworthy events. We get great excitement on the rare occasions when a large passenger aircraft is lost and we pay very little attention to the much larger death toll from the thousands of automobile accidents that are now a fact of life.

However, if we look at present trends, it does seem that search and rescue requirements for downed transatlantic airliners i thankfully, very low. At the beginning transatlantic air travel, it was expected th such incidents would occur quite often; fo tunately they have not. We also do not see to have much of a concern these days ov the rescue of transatlantic passenger liner That is probably due more to their shrinkir numbers than their expert navigation or the fire-proof policies. However, the number offshore drilling units in the eastern Canac offshore is large and increasing. The numb of ships and helicopters needed to suppc them is also increasing and we hope it w go on increasing for production as well exploration.

I doubt that the sequence of events whi caused the loss of the *Ocean Ranger* w ever be repeated, but other major acciden undoubtedly have to be a cause of concer The next one may be caused by a blowo a fire, or on a MODU that is under to rather than drilling. These could occur du ing production as well as during exploratic It is far more probable that what we will fa in the next two years are minor acciden perhaps associated with the supporti ships and helicopters, as well as with t large platforms. These probably deserve least as much attention although they a not as spectacular.

It was illustrated very well in Mr. Klippe berg's paper and by some of the other stu ies produced during the *Ocean Rang* investigation that a characteristic of t requirements for search and rescue, in co nection with drilling on the East Coast, is t need for coverage far from shore because the location of the exploration leases, a for rapid rescue, because of the short ti that people can survive immersion in c water. But nearly all of the search and r cue incidents, other than for oil drill activities are close to shore or on land a many of these have a more serious probl with search than they do with rescue. Ma of them have less urgency regarding speed of rescue. Fixed wing aircraft faster than helicopters and produce a mu greater search rate, though they are not good for rescue. The bases are now loca to give the best service to the large numl of clients and most of those areas are land or close to the shore. The drilling ac ity requires search and rescue resour that are markedly different from those t are needed for all of the other beneficiar Also the drilling industry posesses resources in the right place to conduct search and rescue that they need. would ask, "Should the existing system distorted in favour of the drilling clients should a separate system be created just the drilling activities?" The Governm land-based SAR resources that have b

put in place are in the best place for the other users, but they are not in the best place for the drilling clients.

Some conclusions could be offered as a result of the analysis that we have heard today. Much can be done by measures such as preventive actions including safety training, provision of immersion gear, strobe lights, and other technologies that will certainly make rescue more likely to be successful. We obviously will have to include things like position reporting and the exchange of information as a routine activity so that when trouble arises everybody knows precisely what the situation is. There is a strong case for tasking and equipping by industry of their standby ships and helicopters, ones that are regularly in or near the right place for rescue duties. This may, of course, require the provision of helicopters with necessary apparatus that they may not have to carry for their normal duties, and standby ships may have to be provided with additional apparatus, perhaps for rapid rig-to-ship transfer of personnel. Certainly, rescue training will need to be pressed for at least an adequate number of specified individuals, although perhaps not necessarily for everybody.

We must take full advantage of certain features of the drilling and support activities that do not apply to the other recipients of search and rescue services. For instance, helicopter support activity is concentrated into daylight hours and the approach of ice or storms is probably something that will come with a fair amount of warning. We should reserve the land-based Government SAR assets for those functions which they can perform for the drilling community without detracting from their many responsibilities, such as a large helicopter lift when there is sufficient warning and the use of fixed-wing aircraft for search when there is reason to believe that survivors may be able to live for more than a short time.

We must clearly encourage and support the oil industry in every way so they should improve their knowledge and equipment to prevent major accidents and to make provision for rapid rescue using only the vehicles that are already in the right place.

Summary of General Discussion Following Paper G

Vice-Admiral A.J. Fulton (CAF, retired) spoke about DND's search and rescue system and pointed to the duplication of effort in the development of a contingency plan by both Maritime Command and industry, without any consultation between the two. He criticized this lack of communication and said it is detrimental to the success of safety offshore. He also criticized the marine community's lack of knowledge regarding how to access properly the SAR system. He said that the SAR resources are often called on when it is too late to effect a successful rescue. Vice-Admiral Fulton stated also that SAR resources are there to serve not only the offshore oil industry, but many others, and that, in fact, the oil industry has not really been a big user. While he encouraged the idea that the industry should be required to mount its own system to serve its own needs, he felt that it is up to government to specify what standards are to be expected and how they might best be implemented.

Mr. Per Klem (Ship Research Institute of Norway) asked whether the idea of a standby helicopter had ever been considered. Dr. E. Klippenberg (Norwegian Defence Research Institute) doubted that standby helicopters would ever replace standby vessels, although the relative merits of each have not been examined closely. He felt that weather limitations, particularly in Canada's East Coast offshore, would severely limit their effectiveness. Mr. J.J.S. Daniel (Hollobone, Hibbert) expressed surprise that the Chinook helicopter, with its superior range and carrying capacity, has not been seriously considered as an abandonment and/or rescue vehicle, but Dr. G.R. Lindsey (DND Operational Research & Analysis Establishment) pointed out that it is oversized for most of the incidents which call on the deployment of SAR resources.

Mr. W. Parsons (Newfoundland and Labrador Federation of Labour) asked whether the industry's Safety Committee included any worker representation, and Mr. Ian Denness (Gulf Canada Resources) explained that the Safety Committee is comprised of individuals who each have a certain degree of expertise in safety. He felt that each company represented on the Committee had its own method of ensuring that the views of workers are brought forward to the safety representatives on the Committee.

Mr. Parsons also asked about the degree of worker representation through unionization currently in place in the North Sea. Mr. J. Hielm (Elf Aquitaine Norge) replied that, in Norway, workers' representatives participate in all aspects related to safety, including the research and development aspect.

Mr. Daniel supported the concept of dedicated standby vessels manned with crews with specialized rescue training. Mr. D. Pease (Husky/Bow Valley) commented that the standby/supply vessels currently in use in offshore eastern Canada are the state-of-the-art in such vessels, having high manoeuverability and horse power, and numerous items of rescue equipment. He asserted that, with their specially trained crews, they are superior to the specially built, dedicated purpose, rescue vessels which are available today. Mr. R. Fodchuk (Shell Canada) supported this and re-affirmed that crew training is ongoing and that this includes rescue exercises alongside a rig.

5

REGULATORY SYSTEM

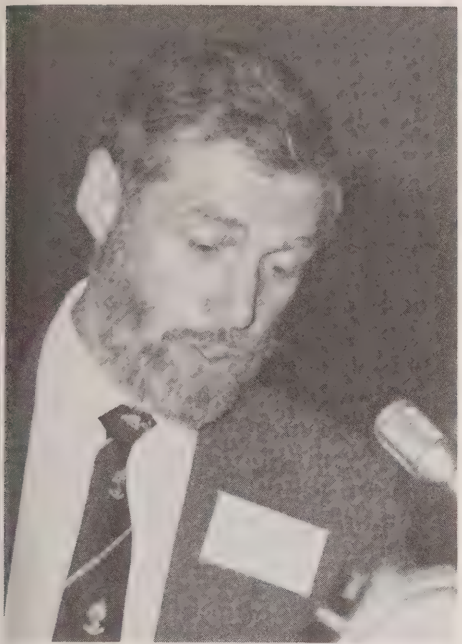
REGULATORY SYSTEM

INTRODUCTION

The studies in this area comprised not only a comparative review of the regulatory regimes of other jurisdictions having offshore industries, but also an examination of the philosophical bases underlying the various approaches to regulatory control.

The Session was chaired by Dr. J.E. Hodgetts, an eminent political scientist and Rhodes Scholar whose teaching career spanned many years at the University of Toronto and Queen's University, with Visiting Professorships at Northwestern, Dalhousie, and Memorial Universities. A Fellow of the Royal Society of Canada, Dr. Hodgetts holds honourary degrees from Mount Allison, Memorial, and Queen's Universities, and has been Editor of the Queen's Quarterly. He currently edits the Canadian Public Administration Series for the Institute of Public Administration of Canada. Dr. Hodgetts is a Past President of the Canadian Political Science Association, and has served on a number of advisory committees, both nationally and internationally. He has written numerous articles and books on Canadian government and administration and served as Editorial Director of the Glassco Commission on Government Organization (1960-1962) and as Commissioner on the Lambert Commission on Financial Management Accountability (1976).

The organization of this Technical Session differed from the previous Sessions in that it did not include any invited commentaries. Instead, the Session consisted of presentations from four panelists who then discussed their presentations as a panel without participation from the Conference floor; the general discussion involving the Conference participants followed the panel discussion.



Mr. I. Manum
Technical Director
Norwegian Maritime Directorate

Mr. Manum graduated from the Norwegian Institute of Technology in 1959 with an M.Sc. in Naval Architecture and Marine Engineering. Since 1969 he has been with the Norwegian Maritime Directorate, and for the last 12 years he has directed the department dealing with hull, machinery, and offshore structures. In this position he has been involved in the investigation of all major incidents of Norwegian ships and rigs. He is also the Norwegian representative on the IMO Maritime Safety Committee.

PAPER H1

A Control Regime and Structure for Effective Maintenance of Operational Safety

INTRODUCTORY REMARKS

Proposed changes in international offshore safety codes in order to improve upon safety are often met with requests for more statistical data that could justify such changes. Even proposals for a start of constructive discussions have been met with the same argument. The practical consequence of such arguments is that we wait for more casualties to occur in order to be convinced. I will assume that both Canada and Norway have had the serious accidents necessary to be convinced of the need for improvements. In addition to the *Alexander L. Kielland* and the *Ocean Ranger* accidents, both the Canadian and Norwegian administrations were involved in the blowout incident on the *Vinland* earlier this year. Although during the incident that unit was evacuated in an orderly and safe manner, the blowout could easily have developed into a serious accident if the gas had been ignited. Therefore, the initiative taken by the the Royal Commission on the *Ocean Ranger* Marine Disaster to hold this conference is highly appreciated by all concerned. The main question before us is: "What is the most effective regulatory regime to ensure that human safety is maintained in offshore drilling and production, including service and supply?"

Before trying to answer this main question, I should like to express my opinion on several topics that could be of some interest. What are the main professional skills involved with the offshore activity in the conceptual, design, construction, and operational phase?

In my opinion the skills needed are primarily traditional, landbased hydrocarbon drilling and production technology and maritime technology (marine engineering, naval architecture, and the nautical profession) and the co-ordination of these.

It is often stated that the offshore industry falls under the umbrella of "fast advancing technology" and that the industry is working on the frontiers. I can accept such a statement regarding the geological part of the technology, but I hesitate to accept it for other parts of the industry. Consider, for example, lifesaving appliances, ballast systems, drill floor equipment, mud systems, testing equipment, etc. In my opinion the technological development in modern shipping has been just as advanced, perhaps even more. In that business, new ways of carrying cargo have been developed and therefore the main characteristics of the ships involved have changed dramatically during the last decade. In order to make them cost effective, those ships are today highly automated and have small crews.

Consider, for example, the design of the semi-submersible, which is the supporting structure of many drilling rigs and accommodation units. That design entered the maritime scene some 20 years ago, when drilling and production expanded into areas of deeper water and a harsher environment. Since then, however, the basic design principles have remained more or less unchanged. Personally, I cannot foresee a fast development of those design principles in the years to come. Further, mobile offshore units (MOUs) are subject to the same environmental forces and conditions which seamen have had to contend with for centuries and which have been the base for marine engineering and naval architecture.

The main question at this conference which I quoted above, seems to be linked primarily to safety offshore eastern Canada. It should, however, be borne in mind that the mobile offshore units (MOUs) carry flags and are transferred from one continental shelf to another. Therefore, international agreement on standards is needed.

REGULATORY REGIME

Responsible Authorities

I believe it would be in the interest of safety if the responsibility for human safety and the encouragement for development of the industry itself were given to two separate governmental departments. However, this is not a very important point, at least not in Norway, because there the government will have the overall responsibility anyway. The number of responsible authorities will depend on what expertise is available within each national administration. In this regard, the two different technologies, oil technology and maritime technology, should be borne in mind. When Norway went into the offshore oil activity, we had no landbased oil drilling and production technology within our national administration. According to the promising results from the North Sea, it was apparent that this activity would become a major part of Norwegian industry in the future and a new and separate directorate, the Norwegian Petroleum Directorate (NPD), was established.

With regard to maritime matters, however, Norway had an established administration and a regulatory regime based on the established regulatory regime for traditional shipping, that also could be applied to the off-

shore oil industry. Therefore, the Norwegian Maritime Directorate (NMD) issued regulations for mobile offshore units. In doing so we took account of the special characteristics of the MOU-design, especially the semi-submersible design.

In carrying out this task, NMD cooperated with other governmental bodies in areas where NMD had limited expertise itself, and for practical reasons some regulatory work and inspections have been delegated to recognized classification societies.

When the responsibility for overall system control is combined with the lack of resources within administrations, there is a danger that the professional skill within each separate technological area is so reduced that the responsible authority becomes "a paper tiger". Therefore, the authority should select some professional areas on the basis of paramount importance to safety, not self-regulation or novelty. Within such areas as, for example, damage stability, lifesaving appliances, and dynamic positioning systems, the administration should carry out a thorough evaluation of the solutions proposed by the industry.

Regulations should preferably give broad objectives and not specify the required means of meeting them. Such means would better be dealt with in guidance notes that could be amended without too much difficulty according to safe practice and industrial development. But the responsible authority must make sure that a minimum level of safety is established. In order to judge the risk associated with various combinations of construction and operational means that would result in a flexible system, trustworthy risk analyses are needed. In my opinion neither the industry nor the authority has the data needed to conduct a quantitative, overall risk analysis. Therefore, mandatory, minimum standards are still needed in some areas of vital importance to human safety. At the same time, risk analyses should be applied to a larger extent to gain experience with the risk analysis technique.

It would be an advantage for all parties involved to know the "rules of the game". It is then easier to make sure that the standards are met, and it allows industry to calculate consequences before starting up an offshore activity. It is argued, however, that this would prevent development within the industry, because there would be little or no room for new solutions. In my opinion, mandatory "rules of the game" should specify the minimum standards, and flexibility should be provided for in the regulations by paragraphs stating that any solution which provides an equivalent level or safety should be accepted.

Development of Regulations

The objective of a regulatory regime is to limit the loss of lives in connection with the offshore activity. When developing regulations, there are two main principles:

1. The identification of factors initiating accident development and elimination or control of those factors;
2. The introduction of means to limit consequences by setting standards for a technical concept or for operational factors, in situations where initiating factors exist.

Overall Responsibility and Control

According to the policy of the Department of Shipping and Commerce which has been adopted by the Norwegian Parliament (Stortinget), the NMD will gradually change its control regime. The object of this policy is:

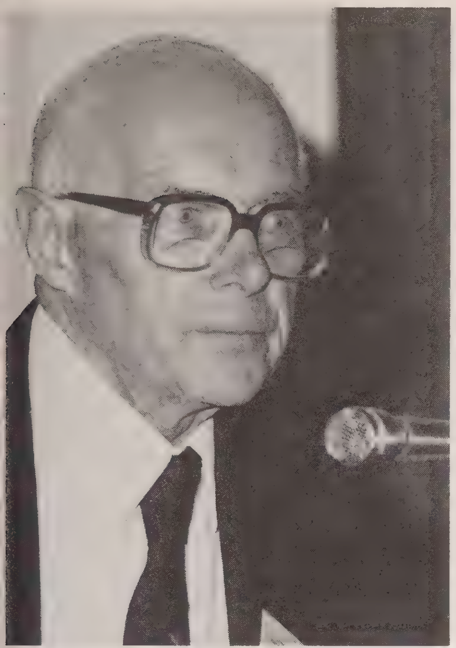
1. To guarantee co-ordination of safety control in all phases;
2. To provide an overall control;
3. To reduce the involvement of the administration in the control of some details;
4. To reserve the resources of the administration for more overall and total control;
5. To take full benefit of the resources of all parties involved;
6. To achieve continuity in the safety work;
7. To provide the administration with a tool for continuous evaluation of the safety regulations;
8. To improve safety standards.

As a first step in this change of the control regime the administration intends to transfer the detailed control in some control areas to the owners as a part of their internal control. The administration will retain overall supervision of the control procedures and their application and will correct them as necessary.

International Co-operation

Mobile offshore units, including drilling units, crane barges, diving support vessels, accommodation units, etc., and supply vessels, are today all transferred from one continental shelf to another from time to time. Some types of units are transferred more frequently than others. For the benefit of the industry, regulatory authorities should provide for easy acceptance of MOUs moving from one continental shelf to another. In order to maintain safety of human life, however, it is important to establish common agreement on uniform principles and minimum standards. The ultimate goal could be a convention with requirements on minimum standards for world-wide operation, with additional requirements for special areas or zones with harsh environmental and/or special conditions. The international body for agreements like this is the International Maritime Organization (IMO). Good progress has already been made regarding supply vessels and diving systems, but the IMO code for mobile offshore drilling units is still inadequate. It has not taken proper account of the special characteristics of the MOU design and operation in comparison with ship design and operation.

I hope that this conference will lead to more constructive contribution and more progressive work from all members of IMO who have relevant offshore experience.



Ir. G.L. Hargreaves
ormer Consultant
I.K. Department of Energy

Ir. Hargreaves, after a 28 year career serv-ng the Royal Navy as a Dockyard Officer, vorked in a number of positions in the Brit-sh public service. Following retirement, he vorked for 7 years as a Consultant to the 'etroleum Engineering Division of the)epartment of Energy, where he was instru-nental in establishing the Offshore Installa-ons Technical Advisory Committee which lrafted the technical and legislative guid-nce on design and construction of offshore tructures.

PAPER H2

A Control Regime and Structure for Effective Maintenance of Operational Safety

INTRODUCTION

This presentation describes the development of measures taken to ensure the strength, stability and seaworthiness of offshore installations in sea areas under British control. Offshore installations are here understood to be the structures, fixed and mobile, that provide a platform for the petroleum related equipment associated with the exploration for, and the exploitation of, underwater petroleum products, for handling and storing those products, and supporting living and working accommodation for the operating crews; most petroleum related equipment and its operation is controlled by separate legislation. But the principles and practices described below are also applicable, in appropriate degree, to other technical legislation.

LEGISLATION

Acts of Parliament

Offshore safety, like other industrial legislation, must be based on the firm foundation of an Act of Parliament, in this case the *Mineral Workings (Offshore Installations) Act* of 1971 (subsequently supplemented by the *Pipelines and Submarine Pipelines Act* of 1975 and the *Oil and Gas Enterprise Act* of 1982). The preamble to the 1971 Act reads:

> An Act to provide for the safety, health and welfare of persons on installations concerned with the underwater exploitation and exploration of mineral resources in the waters in or surrounding the United Kingdom, and generally for the safety of such installations and the prevention of accidents in or near them.

At the time this Act was being drafted it was possible only to speculate on the future size and complexity of the offshore industry; the nature of many of the technical problems had yet to be identified, let alone quantified, and even known hazards could develop unexpected complexities. In these circumstances legislation was drafted as an "enabling Act", which authorised the Secretary of State for Energy to prepare regulations as and when the situation became clearer, when needs had become evident, and when the necessary technical data had been prepared. Regulations can be framed only to meet ends clearly defined in the authorizing clause and subject to any specific conditions laid down in the Act. Parliament and the courts keep a jealous eye on such delegated powers and a Minister who exceeds his authority can find himself in embarrassing trouble!

However, the Secretary of State was given specific authority to make regulations requiring every installation to have a *Certificate of Fitness,* to be granted only after such survey, inspection and testing as might be prescribed. He was also empowered to appoint authorities to apply the regulations and issue certificates. A duty to comply was laid on the owner of an installation, the manager and the concession owner under pain of prescribed penalties, with regulations made under the Act.

Regulations

Unlike Acts of Parliament, which can only be amended by another Act with all its attendant procedural delays, regulations can be altered and amended with less difficulty should the need arise – an advantage when dealing with rapid change.

A safeguard in the 1971 Act requires the Minister to consult with the industry before making regulations but without requiring him to take the advice tendered. In fact consultation took place with the appropriate technical committees of the United Kingdom Offshore Operators Association (UKOOA), where engineer talked to engineer and specialist to specialist and very early on all concerned, realising that their eggs were in the same basket, adopted the un-written principle, "convince or be convinced". Mutual confidence grew rapidly at the corresponding professional levels, to the advantage of both sides.

Made in February, the *Construction and Survey (Offshore Installations) Regulations* came into operation on 1 May 1974. These regulations provide the effective legal backing for ensuring the safety of offshore installations; they set down objectives but do not specify means of achievement. Clause 3 sets out the fundamental requirement that as from 31 August 1975 no installation might enter, or remain in, British waters unless there exists in respect of that installation a *Certificate of Fitness* issued by an approved Certifying Authority. (Certifying Authorities are dealt with in the Section on Enforcement below). Subsequent clauses prescribe the drawings, calculations and other data that must be submitted with any application for a *Certificate of Fitness*; also the access and other facilities that must be afforded to representatives of the Certifying Authority.

Regulations require the Certifying Authority to make a comprehensive and independ-

ent assessment of the whole process of design and construction before deciding that a *Certificate of Fitness* can properly be issued. Certificates are normally valid for five years, subject to satisfactory annual surveys, but may be for a shorter period, and subject to such other qualifications as the Certifying Authority may deem necessary in the light of their assessment. Separate clauses detail the procedures to be followed in the event of alterations, damage, and deterioration. Annual and five year major surveys are prescribed to ensure that an installation remains fit for its purpose; but a continuous survey is also acceptable. These surveys must be carried out under the supervision of, and subject to the approval of, the Certifying Authority. The method of calculating maximum fees that may be charged is set out in special Schedule of the regulations.

Schedule 2 of the regulations is devoted entirely to the technical assessment that must be taken into account by designers and Certifying Authorities. Part I contains definitions and Part II to VIII deal in turn with: environment, foundations, primary structure, secondary structures, materials, construction, and equipment (that is mechanical and electrical equipment associated with the installation itself and not including petroleum associated equipment).

Part II lists the environmental forces to be taken into account and contains the important stipulation that minimum conditions shall be not less severe than those likely to occur not more than once, on average, during any period of 50 years. Parts III to VIII prescribe performance criteria, specifying minimum standards to be achieved in design, materials and construction. Appropriate clauses deal with site investigation, afloat stability, sub-division, and watertight integrity. Part VII, construction, prescribes supervision, material control, quality control, and fabrication techniques, all to be to the satisfaction of the Certifying Authority.

Regulations, like Acts of Parliament, must be written in legal language by a legal draftsman because they should ideally be understood and interpreted in exactly the same way by all lawyers and judges. Engineers and legal draftsmen, each a layman in the other's field, invariably tend to over-simplify the other fellow's task. Each believes he knows exactly what the other is saying and usually both are wrong! Time and patience are well spent getting things right at this stage.

Guidance Notes

Non-statutory documents, not backed by law, are not properly included under legislation but they have been included here because they are intimately linked with the regulations. Simultaneously with the publication of the Construction and Survey regulations, the Department of Energy published, *Guidance on the Design and Construction of Offshore Installations,* 1974, the "Green Book". An 80 page loose leaf book in a ring binder cover, the Green Book was produced in a hurry to meet a need, namely to provide a standard for use by designers and Certifying Authorities in the application of the new regulations. Arranged in sections, Sections 2 to 8 corresponding with Parts II to VIII in schedule 2 of the regulations, the Green Book took the form of a designer's guide, containing information, references to codes of practice and other published material, recommended factors of safety and other information relevant to design and construction. On the advice of their specialist advisors (see section on OFINTAC below) the Department of Energy believed that, applied with judgment by experienced engineers, the Green Book recommendations would meet the requirements of the regulations.

As stated, the Green Book was prepared in haste, against a deadline, and the loose leaf form was adopted to facilitate the amendments that would undoubtedly be needed in the near future. In fact, experience and research results came so fast during the next few years that the department did not amend the Green Book but, instead, brought out a second edition, the "Blue Book" in 1977. In addition to up-dated material in all sections the new edition was nearly 50% larger, consisting of 116 pages, and incorporated enlarged sections on fatigue, helicopter decks, and fire resistant construction as well as completely new material on noise and vibration.

Following the useful precedent described in Regulations under the Legislation section, the content of the Blue Book was also discussed with UKOOA, inter alia allowing the industry to comply with the revised recommendations even before publication. The second edition was well received by the technical press as being better arranged and more useful than its predecessor.

Certifying Authorities and designers are not obliged to comply with non-statutory Guidance Notes but, as one writer observed, "... if an owner complies with them, it goes a long way to establishing that he is acting reasonably." No significant problems have, in fact, arisen. Using the loose leaf amendment system the Blue Book has continued in use to the present day. (A third edition, incorporating all seven amendments so far issued and a new section on fatigue, was published at the end of July 1984.) Owners, designers, and Certifying Authorities may, at discretion, disregard the Guidance Notes when later or bette data becomes available, so allowing max imum flexibility in the application of nev techniques.

TECHNICAL

Offshore Installations Technical Advisory Committee

During the early offshore years the Depart ment of Energy realised the need for a wide range of technical knowledge than wa available in the department, or, indeec within any one department of governmen To meet this need a special group wa established, the Offshore Installations Tech nical Advisory Committee, or OFINTAC as rapidly became known. To this small bu powerful group were nominated representa tives from the:

- Meteorological Office
- Institute of Oceanographic Sciences
- National Maritime Institute
- Hydraulics Research Station
- Building Research Station (soil mechanics, foundations)
- Naval Construction Research Establishment
- Marine Division, Board of Trade (seamanship, marine safety)
- Department of the Environment (civil engineering, steel, concrete)
- National Engineering Laboratory (metal fatigue)
- Department of Energy

Each representative was a specialist standing, some of international reputatio and in addition, each could call upon th resources of his parent organisation. Th writer, with maritime civil engineering bacl ground, was appointed to lead this grou with a primary directive to ensure th "Strength, Stability and Seaworthiness Offshore Structures". Secretarial service were provided by the department.

OFINTAC met regularly once a wee meetings usually lasting all day. Some of th meetings were held at the headquarters an organisation providing members, givir the 'home' members an opportunity demonstrate the extensive resources ava able. In addition, members visited oper tional offshore installations and constructic yards in UK and in other countries. Th close, continuous association between si and laboratory, engineer and scientist, ma ter mariner and 'boffin', led to each memb gaining an appreciation of the problems ar resources of his fellows, and promoted th rapid growth of a group identity with members contributing to all discussions, n merely the specialists most closely co

ɘrned. This attitude proved invaluable. FINTAC operated on the sound principle at in an on-going situation today's probms must be solved with today's knowldge and resources extrapolated only as far s professional judgement allowed; a conɘpt long familiar to engineers and seamen. ne scientists coupled their agreement with rong recommendations for further reɘarch where necessary, leading, inter alia, three additional weather ships being staoned in the surrounding seas and to invaluble fatigue data following full scale tests on rge tubular joints. OFINTAC was mainly sponsible for the technical input to the onstruction and Survey Regulations and to e Green and Blue Books. The group also rried such specific tasks as were referred om time to time and recommended search proposals to fill gaps in knowledge verify assumptions.

Once the Blue Book had been launched, FINTAC considered that their primary sks had been accomplished and sought scharge from its responsibilities. This was pproved by the Secretary of State and the oup was disbanded in 1978. It was a privije to have been associated with so able nd hard working a body.

search

uring the earlier years offshore research as carried out under the auspices of the hip and Marine Technology Research oard. Once approved, a project was aced out to contract with an appropriate search organisation or private consultant. project officer was appointed (each oject officer usually handled four or five ntracts) whose duty it was to keep in uch with expenditure and progress, and bmit periodic reports to the board. At a ter date the Department of Energy sumed responsibility for its own research it no changes were made to the contract stem and project officer control. In due urse the Technical Head of the research ganisation was co-opted on to OFINTAC, eping that group in continuous touch with e status of relevant research contracts. portant projects in which OFINTAC had interest included the additional weather ips in the seas surrounding UK; the NORVAM project, a mathematical wind and ave model based on hind-casting, used to edict extreme and other sea state condins in the North Sea; and the British Offore Steel Research Project, which cluded full scale fatigue tests on large bular joints and provided new data on ale effects.

ENFORCEMENT

Certifying Authorities

Under the 1971 Act the Secretary of State is authorised to appoint Certifying Authorities and empower them to issue *Certificates of Fitness* after being satisfied, by comprehensive and independent assessment, that the design and construction of an installation complied with the regulations. Consideration was given to the possible appointment of the five principal Ship Classification Societies operating in the UK, namely:

- American Bureau of Shipping
- Bureau Veritas
- Germanischer Lloyd
- Lloyds Register of Shipping
- Norske Veritas

Large reputable maritime organisations, effectively non-profit making, they are accustomed to competing with each other for business. Each possessed a world wide organisation of representatives and agents, able to take in their stride the testing and identification of materials and equipment and the supervision of construction and repairs. This was particularly important, as the oil industry is nothing if not international. When approached, all five societies expressed the belief that they had the resources and the staff to undertake the work, but stipulated that the Department of Energy must set the standards to be achieved, hence, the need for the Green and Blue Books! Before appointment, each organisation submitted to detailed inspection of its financial and technical resources and in a majority it was found necessary to stipulate that additional specialist staff be appointed in the fields of civil and structural engineering, soil mechanics, foundations, and reinforced concrete. In every case the societies concerned willingly complied. At a later stage a sixth organization, a consortium of consulting engineers and naval architects, Halcrow, Ewbank and Associates Certification Group, was appointed.

The oil industry is always in a hurry and design is usually only a jump ahead of construction. The Certifying Authorities have found little difficulty in accepting this situation and maintain close liaison with design and designers right from the start; differences are detected and settled as they arise instead of coming to light later to cause delay and disruption.

Petroleum Inspectorate

Clause 6(4) of the 1971 Act empowers the Secretary of State to appoint inspectors to assist him in the application of the Act. At present the Petroleum Inspectorate consists of a small group of petroleum, civil, mechanical, and electrical engineers and occupational safety experts; a former Head of the Structural Branch is, at present, Head of Safety. (Other Inspectorates, operating under separate legislation, deal with diving and with pipelines.) Inspectors carry out regular inspections both offshore and at construction sites during building. A primary objective is to check that the certification system as laid down in the regulations is operating as envisaged and that all stages of construction and maintenance receive the required independent oversight. The Inspectorate is also interested in the continuous and periodic surveys laid down in the regulations and in training. Periodic meetings are held with the Certifying Authorities, both individually and separately, to review experience gained, deal with problems that may have arisen in the application of the regulations and ensure that all Certifying Authorities maintain equivalent standards. Periodic discussions also take place with appropriate departments of foreign governments having interests in the North Sea and adjoining sea areas, again with a view to harmonising control practices and requirements to the maximum degree practicable.

Every few years an inter-governmental Conference of Safety and Pollution is held to review the progress and recommendations of working groups established with a view to harmonising design requirements on working conditions. For example Working Group I, consisting of specialists from France, Norway and UK, was made responsible for preparing and keeping up to date agreed environmental design criteria for the whole of the sea areas of the North West European continental shelf. The Inspectorate plays a major part in these conferences.

Since OFINTAC was disbanded, the Petroleum Division Five, which includes the Occupational and Safety Inspectorate, has assumed responsibility for up-dating the Blue Book, seeking specialist advice as necessary and arranging for the now well established voluntary discussions with the industry.

These paragraphs do not pretend to give a comprehensive picture of the Inspectorate as they ignore the continuing mass of administrative duties, consultations with other government departments, and dealing with the inevitable day to day problems.

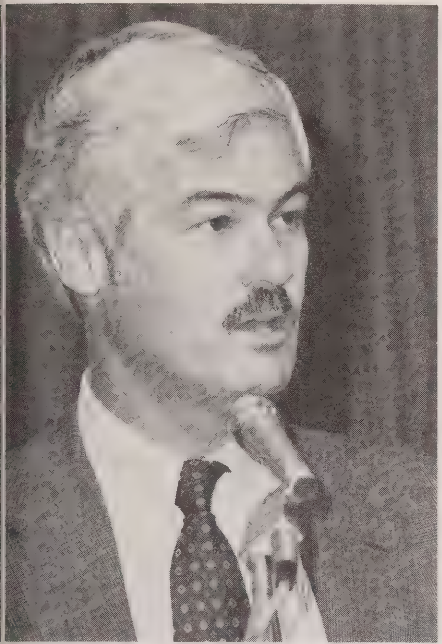
CONCLUSIONS

On the basis of ten year's operations this presentation submits that the measures devised to ensure the strength, stability, and seaworthiness of offshore installations in

British areas have achieved their objectives and represent, if not the ideal, at least a workmanlike compromise between the two extremes of 'self-governing' and 'totally prescriptive'.

Subject to the specified minimum standards being achieved, no constraints are placed on owners, designers, and Certifying Authorities and owners may select the Certifying Authority of their choice. Further, the obligations placed on owners requiring comprehensive independent checks on design, construction and periodic surveys are little, if at all, more than those that would normally be assumed voluntarily by a prudent owner to preserve the lives of his employees and protect his investment.

But no man can afford to be complacent when dealing with the sea.



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PAPER H3

A Control Regime and Structure for Effective Maintenance of Operational Safety

The proper relationship of government regulation and offshore activity is not a new subject for the International Association of Drilling Contractors (IADC). Back in the late '70s, for example, we worked closely with the United States Coast Guard to develop the U.S. flag MODU (Mobile Offshore Drilling Unit) code. We have considered the matter continuously since then. Industry-government relations were, in fact, the subject of one complete session of the Symposium on the Safety of Life Offshore which was held last summer in California. At that conference, which saw participation from both Americas, as well as Europe, we discussed many of the same matters being considered here in St. John's. The conclusion made at the Symposium was that the interests of safety are best served when government and industry work closely together. This conclusion was echoed last fall by the Offshore Safety Task Force of Canada's Eastcoast Petroleum Operators' and Arctic Petroleum Operators' Associations. In their report on offshore safety they noted that:

> Resolution of safety concerns requires a concerted effort of co-operation and communication within the industry and between industry and government (1).

I wholeheartedly endorse the idea that effective and realistic regulations can only be arrived at when industry and government work hand-in-hand. But let us take the concept a step further. The stress has to be on the word "realistic". Safety regulations can only be effective if they deal with real-world situations in a reasonable way. First and foremost, we must resist the impulse to regulate purely for regulation's sake. Nor should regulations be used as a club against business. I am not delivering a diatribe. This sort of thing does happen.

In her book, *The Apocalyptics*, Edith Efron documents the way that some leaders of the scientific community, who are philosophically hostile to business in general, have systematically shaded facts to "prove" cancer in humans stems principally from industrial causes. Yet the most thorough study of the subject indicates that only a very small fraction of human cancers, maybe five percent, can be directly attributed to industrial chemicals (2). Here is a telling quote from Efron's book that distills this hostile attitude toward business:

> The notion [is] that the essential problem of 'regulatory' science is a conflict between good and evil, between regulators who seek selflessly to protect our lives and businessmen who seek selfishly to kill us all (3).

That is an extreme statement, but we should recognize such an attitude exists. We must be very cautious not to let it creep, however subtly, into the regulatory process.

We also have to be very cautious about the "high-tech" approach to safety regulation. In the wake of both the *Alexander Kielland* and *Ocean Ranger* disasters, we heard a cry for gadgets, redundant systems, and electronic cures of all sorts. But could they have prevented either mishap? The *Alexander Kielland* was built under one of the most stringent regulatory regimes in the world, yet human error in the shipyard caused the sinking. Offshore rig design was clearly equal to the storm that claimed the *Ocean Ranger*, because both the *SEDCO 706* and the *Zapata Ugland* came through the same blow without incident. Again, it appears human error was at fault. In these two cases at least, better training is what we needed, not better technology. The economic forces that drive the petroleum industry ensure that every offshore operator will seek the best available and safest technology, just to remain competitive. This is what I mean about realistic solutions to real-world problems. If you are going to write regulations that work, and that do not strangle industry in the process, then you must have a detailed knowledge of the industry you are seeking to regulate.

Unfortunately, it is not unusual for governments to rely on the opinions of unqualified experts. A co-operative working arrangement between government and industry can provide the operational expertise needed to draft effective regulations credible to all concerned. This is not to imply that there have not been some sincere efforts to gain industry advice regarding the Canadian offshore, but often regulators went to the wrong people. They talked to the oil companies, but not the drilling contractors, and those are two very different businesses. Earlier this year, for example, a group of oil company executives met under the auspices of Texas A & M University's Sea Grant Program to discuss offshore safety. What was their conclusion? Here is an excerpt from a report on the conference:

> Offshore in the oil patch, most producers blame their contractors for any problems that may exist, although the larger oil companies differ among themselves as to how serious the problem is (4).

Needless to say, we, the contractors, take exception to that conclusion. My point is that offshore drilling companies are part of

the oil industry, but they are different from oil companies. This is a critical distinction, but few people make it.

There are many concerned and very able individuals working in government today. Not many, however, unless they have retired from the industry, can claim the detailed understanding of offshore activity that our workers have. Government must have the expertise of industry to do an effective job of regulating industry. What then, is the proper role of government? I am sure a few people in this room today would have some interesting answers to that question. But the question is a fair one, and deserves a fair answer. A narrow definition of the role of government in offshore activities was given by the Marine Board of the National Research Council in Washington in a recent publication entitled *Safety Information and Management on the Outer Continental Shelf.* The government's role, they said, is to:

> Motivate industry to conduct operations safely, to disseminate information, and to foster the development and application of technology that will improve the safety of OCS operations (5).

I agree with that, but I think we need to take a broader view. Government has a responsibility to look to the bigger picture. Business must, of necessity, concentrate on specific tasks. Government has the task of pursuing the greater good for all of the people. The problem comes in sorting out this mandate and balancing the demands of differing interests.

I think most of us in the offshore industry agree that early pressure from provincial authorities to employ local residents, while understandable and applicable in certain activities, was probably a mistake. There is no question that this practice can lead to poor results in areas where a number of years and experience is needed. There was really no need to force the issue, because the economic facts of our business dictate that drilling contractors operating in foreign waters begin to employ local residents as quickly as possible. The expense of transporting entire crews across a continent or an ocean is prohibitive over the long term. A good example of this process is the *Zapata Scotian*, which started working off Sable Island two years ago with a largely U.S. crew. Today, the *Scotian's* crew is 91 percent Canadian. Happily for us, more than half the Canadians we hired already had at least some offshore experience. But for those that did not, it has taken fully two years to bring them up to snuff. And this is a better track record than we find in the U.S., because our Canadian employees are generally better educated, have better work records and are more serious about their work. But the process takes time, in this case, two years. Because the offshore industry is so new, you cannot hire a full complement of rig-wise personnel off the street. And when you are working with very expensive and complex equipment in difficult and even dangerous environments, you run a great risk if you are forced to use unseasoned people. This risk can be avoided if there is a mechanism in place that enables government officials and offshore operators to work together to achieve common goals. Such a mechanism is not a pipe dream. There are several good examples we can point to right now.

One is the Panama Offshore Industry Committee. Let me share with you a comment by Doctor Hugo Terrijos Richa, Director-General of Consular and Maritime Affairs for the Republic of Panama. He says the Panama Offshore Advisory Committee has provided the industry:

> the opportunity to participate in the early stages of development and implementation of all kinds of regulations and requirements, and has also provided them with an excellent information channel on all the maritime administration activities. At the same time, the committee has permitted the administration to benefit from the vast pool of know-how and experience represented by the [industry] (6).

Why did Panama need industry input? They already had considerable experience with maritime affairs. They sought industry advice because they recognized that most of the time the offshore industry deals with drilling. The principal marine skills are normally brought into play perhaps five percent of the time when the rig is being moved.

Most of our leaders in the offshore industry come from the drilling side of the business and learn the necessary marine skills. The Panamanians recognized this duality and adopted the perspective that led to a regulatory regime which encourages a productive offshore drilling industry. We get a similar, very positive report about the working relationship between industry and government in the United Kingdom. Industry input is sought at an early point, and joint industry-government meetings are set up to review intended regulations as a routine part of the code-making process. A like system now appears to be working pretty well in the United States, though there was a bit of rough sailing early on. Today, the United States Coast Guard, which has primary responsibility for safety on the Outer Continental Shelf, actively seeks industry cooperation in drafting regulations.

A timely example is the current work being done by IADC member companies to prepare an in-depth analysis of marine skills and knowledge for presentation to the U.S Coast Guard to be used as a basis fo developing future licensing regulations Addressing the Symposium on the Safety o Life Offshore last year, Captain Thomas Tuf wiler, Chief of the U.S. Coast Guard's Mer chant Vessel Inspection Division, describe his mission this way:

> The goal of government is to ensure an acceptable level of workplace safety without overburdening industry to the extent that it is uneconomical to develop seabed resources. Government agencies cannot isolate themselves in establishing workplace safety rules. Agencies must become familiar with the industries they are regulating in order to determine safe practices that are at the same time economically feasible (7).

Canada today has a rare opportunity. Of shore development is comparatively ne here, and you are not bound by decades o ponderous precedents. With this clean slate you have the opportunity to write one of th best regulatory regimes in the world. Bu please do not get carried away. Canada like most nations, has some peculiar needs But if you write regulations so specific tha they are out-of-step with the world commu nity, you will hog-tie offshore activities her for years to come. The nature of the of shore industry demands that drilling con tractors regularly move in and out of th waters of many nations. We must have high degree of uniformity of standards, if w are to remain operationally and econom cally viable. If there is any way possible, w in IADC ask that Canadian regulators exam ine the possibility of having identical licens ing and personnel requirements for all o North America, perhaps generating a reali tic pattern for other nations. Beyond this, want to strongly suggest that in drafting of shore regulations, Canadian officials loo long and hard at the considerable effort th International Maritime Organization has pu in on this subject. The IMO has drafte several internationally applicable safe codes for offshore operations. This entirely appropriate, since the IMO is th only body I can think of that comes close being truly representative of the interna tional maritime community. This is not say that we agree with absolutely everythin that the IMO has done. For example, we c not agree with the final way in which som technical questions were resolved in th IMO's MODU code. But the Internation Maritime Organization has been consci tious in seeking the input of industry in th code-crafting process. And it does provi a truly international forum for considerin safety and other maritime matters.

I want to make one more suggestion wi

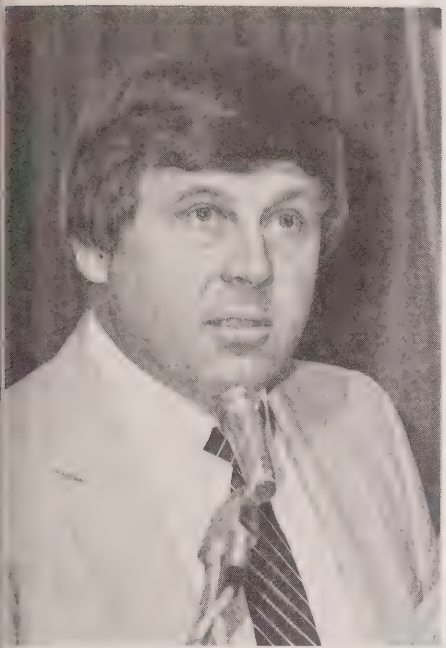
·gard to establishing a Canadian regulatory ·gime; give the responsibility entirely to a ngle agency. One of the most bewildering ·oblems we have run into in the Canadian ffshore is the herd of agencies that have a and in the regulatory process. For exam- e, at the federal level you have the anadian Coast Guard and the Canadian il and Gas Lands Administration, not to ention Revenue Canada, and Customs nd Immigration. Then, there is the New- undland Petroleum Directorate, the Minis- y of Labour and Manpower, various Nova cotian agencies, and others. All of these e in addition to the regulatory agencies of ag country of the drilling rig, and the vari- us classification societies. This often sults in multiple inspections with all the dundancies that implies. I know in one ase, we had to run the same ballast control ill several times as one agency after nother came out to make sure we were oing it right.

submit that the Canadian Oil and Gas ands Administration should be the lead ganization for the regulation of safety off- iore. I want to urge COGLA, however, to ly strongly on the Canadian Coast Guard r sound advice. Coast Guardsmen are ariners; they learned their craft "out in the eather" and they understand what safety n the seas is all about.

The sinking of the *Ocean Ranger* was a eat shock for all of us here today. We cer- inly felt it in a visceral way at Zapata ecause the *Zapata Ugland* was one of the o rigs that weathered the storm that aimed the *Ranger*. All of us in this room ave spent a good deal of time during the ast two years assessing this tragedy, just s we did following the sinking of the *Alex- der Kielland* two years before that. Where anges have been needed, changes have en made, particularly in the area of train- g. The *Ocean Ranger*'s owner, ODECO, r example, established a Marine Division ecifically charged with the training and rtification of marine employees and super- sors. I think we all have a stronger aware- ss of the marine side of our business than fore. Additional changes may be needed, d regulations may be required to insure mpliance with them. But it would be a rious mistake to gush forth with a knee- k flood of new, unwise and untested regu- ions, just to satisfy a political mandate to lo something." The hardest task of all is to ke the time needed to do the job right hen you are surrounded by a clamour for stant action. The Royal Commission on e *Ocean Ranger* can be the vehicle for afting one of the most modern, effective d successful offshore codes in the world day. We have only to continue to work gether.

References

(1) "Eastern Offshore News" Canadian Petroleum Association (St. John's, Newfoundland: December 1984), p. 3.
(2) "Fortune" Time, Inc. (Los Angeles: July 23, 1984), p. 127.
(3) Ibid., p. 130.
(4) "Ocean Science News" Nautilus Press (Washington: June 11, 1984), p. 1.
(5) "Safety Information and Management on the Outer Continental Shelf" Marine Board, National Research Council (Washington: 1984), p. 7.
(6) "Proceedings from the Symposium on the Safety of Life Offshore" Scripps Institution of Oceanography (La Jolla, California: June 1983), p. 63.
(7) Ibid., p. 54.



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PAPER H4

A Control Regime and Structure for Effective Maintenance of Operational Safety

INTRODUCTION

The purpose of this presentation is to provide an overview of the Canadian regulatory system from the perspective of the Canadian offshore petroleum industry. My remarks will focus on the regulatory system as it relates to safety and exploratory drilling off Canada's East Coast. The presentation is divided into three parts:

1. A brief description of the present regulatory regime;
2. An overview of the concerns and problems industry has with the present regulatory practices;
3. Some constructive suggestions to assist in improving the effectiveness and efficiency of the system.

THE EXISTING REGULATORY SYSTEM

The existing regulatory system in Canada involves a number of government departments and agencies, both federal and provincial, having a wide range of responsibilities. Government, through its various agencies, administers numerous policies, acts, regulations, guidelines, standards, and directives relevant to offshore petroleum activities.

The federal government, through the Canada Oil and Gas Lands Administration (COGLA), administers acts and regulations relevant to land tenure and drilling operations on Canada's continental shelf. Specifically, these include the *Canada Oil and Gas Act*, the *Oil and Gas Production and Conservation Act* and the *Canada Oil and Gas Drilling Regulations*. All activities associated with the exploration of oil and gas must be authorized by COGLA. COGLA inspects and monitors operations, ensuring activities are conducted in an operationally and environmentally safe manner and that national and regional benefits are provided. Government controls industry's offshore exploration activities through a detailed application and permit system. It is the responsibility of the operator to demonstrate to the government that its drilling operations can be conducted safely. This system is designed to ensure that operators' plans comply with government regulations before any drilling takes place. Once underway, government monitors operations and enforces regulations. The interaction between the federal government and the offshore exploration industry is shown on the accompanying figure.

Each oil company operator first enters into an Exploration Agreement with COGLA. An Agreement specifies the interest holder's rights on certain lands and commits the company to a program of activities during the term of the Agreement, usually from three to five years. A Canada Benefits Plan contained within the Agreement states the industrial, employment and social benefits expected from the activities. When an operator plans to commence drilling operations it first applies for *Drilling Program Approval*. This Approval permits the company to use a certain drilling unit within a specified region during a particular time frame. The operator provides COGLA with a detailed description of the drilling program, including information on the drilling unit, training and qualification of personnel, contingency plans, operating manuals, proof of financial responsibility, and an overview of the geology, possible seabed hazards and operating conditions at the drill site. Government reviews and evaluates the application and inspects the drilling unit and equipment.

Upon receipt of *Drilling Program Approval* the operator then submits its application for *Authority to Drill a Well*. In this application the operator provides additional information on specific well programs and updates the description provided in the *Drilling Program Approval*. COGLA reviews this submission and, if found acceptable, authorizes the drilling of the well. Once authorization is received and drilling is underway, COGLA monitors and inspects operations while enforcing regulations. COGLA retains close contact with the operator on its daily activities and monitors the operator's fulfillment of the drilling program plans. The operator must conduct its operations according to regulations, guidelines, and directives. Failure to comply can result in withdrawal of the drilling authority.

The Canadian Coast Guard also has responsibility for offshore safety through its administration of the *Canada Shipping Act*. The Coast Guard controls and approves the design and construction of the marine components of drilling units and support vessels, their safety equipment, and the staffing of vessels. A *Memorandum of Understanding* between COGLA and the Coast Guard specifies their respective activities. Several other federal government departments, agencies, and advisory groups such as the Ministry of Transport, Department of Communications, Department of Environment, and the Canada Employment and Immigration Commission, have consultative roles to COGLA on matters pertaining to safety, communications, environment, employment and labour practices.

The provincial government of Newfoundland and Labrador, through its Petroleum Directorate, also administers legislation and regulations relevant to offshore drilling operations. Other departments are involved in training, safety, local preference purchasing, and emergency measures. These provincial regulations overlap with federal activities.

Under the Canada/Nova Scotia Agreement on Offshore Oil and Gas Management and Revenue Sharing, the COGLA Nova Scotia Office was established under the direction of the Joint Canada/Nova Scotia Offshore Oil and Gas Board. Offshore exploration activities are subject to federal legislation and regulations. Provincial representatives provide an advisory role to COGLA in COGLA's routine administration of industry's exploration activities. Personnel from the Nova Scotia Department of Mines and Energy also work with industry, COGLA, and other provincial departments on matters pertaining to exploration activities.

The regulations and requirements of the federal and provincial governments are comprehensive, covering virtually all aspects of exploration activities such as drilling, well control, evacuation procedures, fire prevention and handling, navigation, electrical standards, and personal safety.

In summary, it can be seen that the petroleum industry is heavily regulated by numerous government agencies. Both the regulations and the regulatory regime are elaborate, complex, and intricate.

CONCERNS AND PROBLEMS

Industry has a number of concerns and problems with the present regulatory system. I will address four of these concerns:

- Problems associated with administrative overlap and complexity
- The inflexibility of certain regulations
- The practical problems of implementing regulations
- The procedure of developing regulations

Regulatory Overlap, Inflexibility and Complexity

In its recent review of safety practices in the Canadian offshore, the industry-sponsored Offshore Safety Task Force identified certain deficiencies, overlaps and conflicts in regulatory requirements. For example, different regulations were found to have inconsistent requirements for survival craft, life rafts, and life buoys. Canadian regulations have been designed to regulate both shipping and drilling operations. Problems have arisen when trying to regulate these distinct activities simultaneously.

It should be remembered that the offshore petroleum exploration industry is an international business. As many offshore drilling units are foreign-registered, there are instances where Canadian requirements differ from those of the flag state. This has created some confusion.

Detailed regulations in some offshore areas have caused difficulties and inefficiencies to industry and regulators. Overly detailed regulations can result in preference being given to the judgment of the regulation-writer over the judgment of the designer or operator. In many instances the regulation-writer does not have all of the required information for a specific operation. This is a particularly important concern in Canada where site-specific solutions are required to accommodate various operating conditions.

Certain regulations are too rigid. Canada's offshore regions vary considerably (such as differences in sea state, ice conditions, and remoteness) and often require unique solutions in order to operate safely. Because technology changes rapidly, industry believes regulations should be flexible enough to ensure that the best available technology is used. In general, we suggest that regulations should specify performance standards rather than particular techniques or procedures to be followed. This would ensure the flexibility we need.

Some obsolete regulations are in effect in Canada which require revision, updating or deletion. Obsolete regulations as well as deficiencies, conflicts and rigidity in regulations may have an undesirable effect on safety.

Implementation

The oil company operator, having received authorization to drill the well, is responsible for the safety of its operations. The operator in turn relies upon contractors to undertake a variety of tasks on its behalf, such as providing drilling services, helicopter support, and supply vessels. The operator ensures that the drilling contractor conforms to the operator's internal policies and with government regulations through terms specified in the drilling contract. The task of managing several contractors and sub-contractors, while ensuring that all pertinent regulations are being complied with, provides a significant challenge to industry in time and expense. Industry recognizes the important role and responsibility of government in regulation. There is room for improvement, however, in regulating industry's activities with greater efficiency and effectiveness. We would like to see our resources utilized more effectively and directed to promoting safety.

The Regulation-Making Procedure

Until very recently, and with the exception of the Coast Guard Marine Safety Advisory Council, no formal procedure existed which solicited industry input on offshore marine safety matters. The process of developing regulations is not a clearly-defined process. No specific administrative process resolves conflicting regulations and no regulatory process systematically promotes the adoption of better technologies. The timing of industry's participation in the development of new regulations has not been consistent. If industry's input into the regulatory process is limited to review of final drafts of regulations, then certain opportunities for developing effective regulations may be lost. Despite inadequacies in the system, COGLA and the offshore industry currently cooperate in the development of offshore drilling regulations. As well, the Canada Lands Safety Advisory Committee was recently formed to address various safety issues and to provide a mechanism for industry input into offshore safety concerns.

IMPROVEMENTS

Although the petroleum industry meets and in many cases exceeds existing regulatory requirements, we believe there is a better approach in managing offshore safety in Canada. The key elements of an effective control system can be envisioned. First, industry and government should recognize the limitations of regulations. Regulations are only one component of a comprehensive control system which provides safety management. A fundamental and common objective of industry and government must be to provide a safe working environment for offshore operations. In our view, the best control system would incorporate three key features. First, it would provide high standards of safety. Secondly, it could be implemented efficiently and effectively and thirdly, it would provide a mechanism which corrects problems in the system and initiates positive change in a timely manner. A control system with these features would be effective without being unnecessarily complex.

The best control system for achieving safe operations is characterized by clarity, consistency, and ease of implementation and monitoring by the operator, contractor, and regulator. It would provide flexibility when applied to different offshore regions in Canada and would encourage the use of improved technologies while providing stringent performance safety safeguards. Industry actively supports these types of positive changes to the regulatory system.

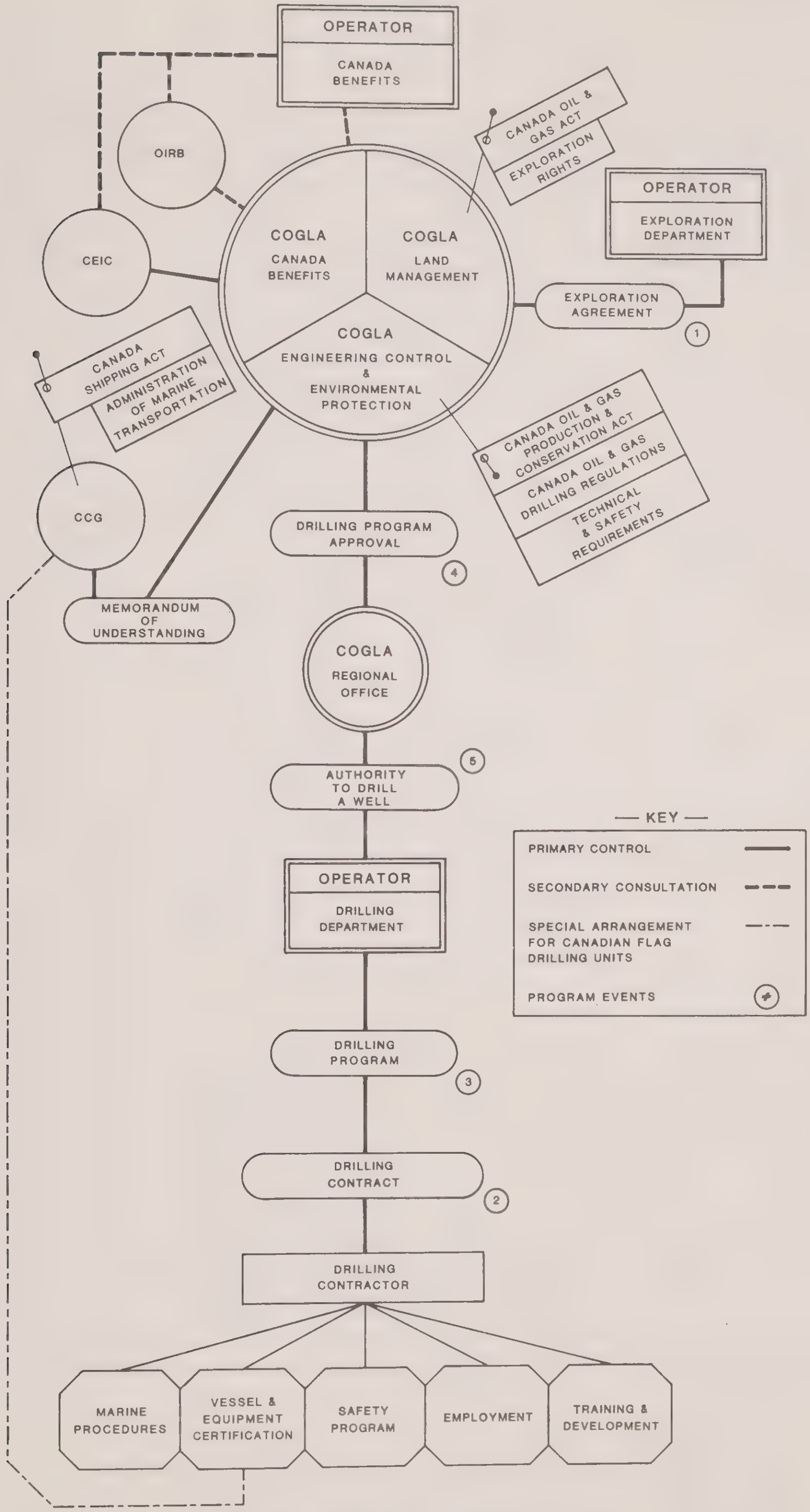

FIGURE 1 (Source: Manadrill Drilling Management Inc. "An Evaluation of Industry Safety Management in Eastern Canada Offshore Drilling Operations.")

Effective, Efficient, and Flexible Regulations

Highly detailed regulations have not necessarily resulted in greater safety. A modest degree of detail in regulations is the most appropriate solution to providing safety in an efficient and effective manner. Regulations need to be simplified. Complicated regulations can be confusing and may be applied inappropriately. With more appropriate regulations, industry would be better able to manage its operations in a more effective manner. A less detailed body of regulations consistent with one another would remove the confusion surrounding the large number of complex and intricate regulations. Canadian marine-related safety regulations applicable to offshore exploratory activities should include international, national, and regional considerations (such as differing standards and operating conditions) to minimize conflicts and provide compatibility among regulations. Continental Shelf Act legislation would resolve much of the jurisdictional confusion and legal uncertainty now present. As well, a means should exist to upgrade regulations systematically with the best available safety technology. Regulatory overlap, conflicts, and deficiencies should be minimized and resolved jointly by government and industry. Government and industry should review the regulatory system to establish which types of operations require highly detailed and specific regulations and those requiring flexible and general regulations which set performance standards. Although monitored by government, industry would be left to achieve these standards. It must be recognized that regulations are only one component of a control system. Regulations alone do not adequately achieve the other requirements of safe operations, those of competent personnel having an ingrained attitude of safety, and of effective communications between regulator, operator, and contractor.

Commitment and Attitude

Industry recognizes that competent personnel are the key to safer operations. Continuing emphasis on safety by all industry personnel is necessary to ensure safety. Companies' policies, training, and practices must reflect this commitment. Safety must be an integral part of the attitude of all persons involved in the operations: workers, supervisors, and senior management. Training, attitude, and good working conditions reduce the potential causes of accidents from human error. Commitment and attitudes cannot be legislated nor regulated. Personnel are better able to perform safely when motivated by an attitude of "safety first", than for the reason of compliance with regulations. Emphasis should be placed on results rather than on mere compliance.

A Mechanism for Improvement

Ensuring safe operations is a joint effort by government and industry. Each has its roles and responsibilities. In authorizing an operator to drill a specific well, government places the onus on the operator to demonstrate that its program can be conducted safely. Government inspects and monitors operations to ensure that the operator complies with regulations. The operator has the ultimate responsibility for the safety of its operations. Charged with this responsibility, industry should have a full opportunity to work with government in making existing regulations more effective and be involved at an early stage in the development of any new regulations and guidelines. Both parties would determine the requirements of new regulations in terms of level of detail and how best to implement the regulation. Industry could apply its practical experience in operations to the design of regulations and guidelines. Industry would provide its perspective on the effectiveness of proposed regulations, its context in operational realities, and whether safety can be improved by the adoption of the regulation. In certain cases the responsibility should be delegated primarily to industry to develop its own guidelines. Through a joint government-industry forum, existing problems with the regulatory system can be addressed and resolved and more effective regulations and requirements can be developed.

Industry Experience

The petroleum industry has conducted offshore exploratory operations in Canada for over 20 years. To conduct these operations safely required a conscientious effort by operators and contractors in providing properly designed and constructed equipment as well as experienced and well-trained personnel. Industry has demonstrated its commitment to safety. Industry has powerful incentives which necessitate this commitment: its financial investment, the prospect of oil and gas production, and its investment in people.

Progress

The EPOA/APOA Offshore Safety Task Force published a report in December 1983 with numerous and specific recommended actions on a range of offshore safety issues. All of the recommendations have been reviewed and actions are underway by industry and by government. We have seen a commitment by industry and government to make improvements in the present regulatory system. During the course of, and subsequent to, the Offshore Safety Task Force study, industry has introduced numerous changes to its operating procedures and management functions related to offshore safety. Government also has responded to certain of the problems identified by industry and has introduced changes to the regulatory system. Maximum cooperation and dynamic communications are required between industry and government to ensure that the improved safety of offshore operations is an ongoing process. The Royal Commission has furthered this cause through this conference and through its investigation of practical means to improve the safety of offshore drilling operations off the East Coast. Judging from the progress made in recent years, we are confident that operations offshore Canada can be conducted effectively, efficiently, and safely.

Summary of Panelists' Discussion

Session Chairman Dr. J.E. Hodgetts brought forward for discussion two issues which came to light in the presentations of the panelists: 1) that industry prefers to deal with a simplified organizational structure with a minimum of administrative overlap in its dealings with government, taking into account the Canadian setting of federal/Provincial relations; and, 2) that the view of industry towards broad, discretionary self-regulation is an unrealistic suggestion.

Mr. I. Manum (Norwegian Maritime Directorate) related Norway's experience with having a preponderance of regulatory bodies to control various aspects of the offshore industry. He said that Norway has reduced the number of agencies to a more manageable size, but there is still more than one. This, however, has not posed serious problems, as Norway does have just the one certifying authority which issues the letter of compliance based on the work provided by the existing regulatory bodies. Therefore, he said, industry is not confused about who the certifying authority is.

Mr. G.L. Hargreaves (Consultant, U.K.) agreed that, because government is always a growing organization, the problem of too many regulating agencies will always be there, not only for the industry who must deal with the agencies, but also for the government itself. It is difficult to avoid administrative overlap, but interdepartmental arrangements can be arranged, for example, the U.K. Dept. of Energy enforces the rules of the Health and Safety Executive. Nevertheless, Mr. Hargreaves thought the best that could be achieved would be to reduce the number of channels with which industry must deal, as one single authority is not a reasonable alternative.

Mr. C. Bonke (CPA Offshore Operators Division) expressed the industry view that the single window approach, as is seen in the Canada Oil and Gas Lands Administration, avoids problems in complying with regulations and is a preferable means of dealing with regulatory controls. Mr. Bonke clarified the industry's view on self-regulation as being a mix of both industry and government involvement. He maintained that regulations should be realistic.

Summary of General Discussion

Mr. T.S. McIntosh (IADC) addressed the issue of regulation through a single government source and said that, in Canada, there should be only one agency, such as COGLA, with which the industry should have to deal with regard to regulatory requirements. He criticized the practice of throwing the industry into the midst of intergovernmental squabbling and urged that these problems be solved without involving industry.

Mr. McIntosh also addressed self-regulation by industry and pointed out that industry would respond in a responsible manner if given a direct charge. An element of trust, however, is required for this approach to be successful. Mr. McIntosh suggested that governmental regulation is no more infallible than regulation by industry. To avoid problems, he encouraged an approach which would have industry draft regulations as required, have their technical soundness verified by an independent certifying agency (such as a classification society), and have the governmental agency which is in authority give the final say.

Mr. Leo Brandon (COGLA) outlined the methods COGLA currently employs to regulate the offshore industry. He first of all emphasized that COGLA is in constant dialogue with the Canadian Petroleum Association and the Independent Petroleum Operators Association so that industry actually does have some input into the regulation-making process. He referred to the Canada Lands Safety Committee (comprised of industry and government representatives) which has been established to encourage dialogue aimed at increasing safety within the industry. COGLA also issues guidelines to enhance the regulations for the industry and to make regulations which are generally a little more specific for the purpose of implementation. Standards are another avenue for control and COGLA contributes financially to the offshore-related work being done by the Canadian Standards Association towards the development of relevant standards. Mr. Brandon pointed out that, in addition to regulation through acts, regulations, guidelines, and standards, COGLA has the option of withdrawing the Operator's Permit to Drill, although this option is not often used.

Mr. Brandon also referred to the involvement of the Canadian Coast Guard in the regulatory process, which has resulted from an increasingly evident indication that the marine aspects of the offshore industry are more relevant to their areas of concern. This involvement has been formalized in a Memorandum of Agreement between COGLA and the Canadian Coast Guard.

Mr. R.A. Quail (Canadian Coast Guard) agreed that Canada is indeed trying to provide industry with one window service through COGLA. Coast Guard administers the *Canada Shipping Act*, applying it not only to the flag rigs but also to rigs drilling in Canada waters, through the drilling permit issued by COGLA.

The Marine Safety Advisory Committee of Coast Guard provides the means for consultation, negotiation, and input by industry (owners, operators, and workers) and government towards the development of regulations which are realistic.

Professor W.G. Carson (La Trobe University, Australia) reminded participants that it was the lack of detailed and enforced regulations on the training of ballast control operators which resulted in the *Ocean Ranger* disaster and, hence, the Conference. That training of ballast control operators has not changed drastically since the *Ocean Ranger* is an indication that industry is not self-regulating, even after lessons such as the *Ocean Ranger*, and it should, therefore, not be allowed to be self-regulating.

The political and economic context in which the *Ocean Ranger* incident occurred, falling as it did between several regulatory regimes, should be taken into account in future considerations of regulatory control and the responsibility of its enforcement.

Professor Carson suggested that, for maximum input to the occupational health and safety of workers, organized labour should be involved in framing and implementing the regulatory regime in offshore eastern Canada. He cited the example set by other jurisdictions which have involvement from management, unions and government regulators. He suggested that the Commission recommend unionization of offshore eastern Canada in its Part Two Report. Mr. V. Greif (SEDCO, Inc.) referred to his experience in a unionized setting in offshore Australia, and found it to be self-defeating and disruptive to operations. He opposed the idea of unionization in Canada's East Coast offshore. Mr. I. Manum (Norwegian Maritime Directorate) commented that Norway, which uses close cooperation with unions in all respects, such as making regulations and funding research, is experiencing no difficulties with union participation. Mr. N. Letalik (Dalhousie Ocean Studies Program) asked whether it has been shown conclusively that

union involvement in the offshore oil industry has had either a positive or negative effect on operations. Mr. McIntosh responded that in his experience, unions have been neither inherently bad nor inherently good, and that a great deal depends on the individuals involved. He said that the accident record of Zapata on rigs around the world is independent of whether unions were involved.

Mr. G. Yungblut (EPI Consultants) asserted that industry involvement in the formulation of regulations is not only desirable, but also necessary, since the industry is where the expertise is, and only their involvement will lead to the generation of practical, reasonable, and useful regulations. He did, however, point out that industry has in the past been agonizingly slow in responding to requests for standards and wondered what could be done to speed up this process. Mr. McIntosh felt that giving industry a deadline would achieve the desired results, but advocated that heavy industry involvement in the drafting and implementation of rules and regulations, with the attendant governmental supervision, is preferable to total self-regulation. Mr. Manum said that in Norway regulations are created to prevent accidents and are therefore based on the results of studies or inquiries of accidents and of their causes.

With regard to developing guidelines, Mr. Greif spoke about the appropriateness for industry of the open dialogue that exists in Canada and the U.K. sector of the North Sea, as well as the systems in those jurisdictions which use independent, as well as government inspectors. He said that the Norwegian regulatory system is far too over-regulated and inflexible, and tends to work against industry. Industry is receptive to the Canadian approach which uses guidelines and dialogues which permit industry to have input into the regulation of their affairs. He encouraged the practice of governmental regulators gaining familiarity and experience by working in the industry on a variety of MODUs in various jurisdictions.

Dr. E. Gold (Dalhousie Ocean Studies Program) cited continuing efforts during this century, particularly by the Commission which investigated the *Titanic* disaster, to upgrade the regulatory regime as it is applied to shipping, but industry even then resisted change and advocated self-regulation. With the exception of the nuclear industry, there has never been any industry successful in either self-regulation or cooperative regulation; therefore, there must be effective governmental regulation and enforcement. Dr. Gold pointed to the Norwegian method of formulating and administering regulations as a good model.

Dr. Gold expressed concern about the effectiveness of an international organization like IMO which takes an average of seven to ten years to set standards which achieve the lowest common denominator for marine safety. These standards offer some guidance but are unacceptable for drilling in the Canadian offshore environments which have unique conditions requiring unique standards. While the functioning of IMO is improving, there is a question about its jurisdictional effectiveness over MODUs, and this remains to be resolved. Furthermore, the Maritime Safety Committee of IMO, which is comprised primarily of Norwegian representatives, tends to be susceptible to pressures from the shipping industry, the oil industry, and the insurance industry. Dr. Gold also referred to the question of enforcement of IMO standards. He felt that as long as oil rigs are subject to flag state and limited coastal state jurisdiction, enforcement will not be effective because many rigs are still under open registry flags.

Mr. Manum responded to the suggestion that IMO provides only minimum standards by saying that even those have value as a base for expanding the standards. The IMO code for MODUs does need improvement, and this is one of the primary goals of IMO at present. Mr. Manum did not think that enforcement is a great problem, since most coastal states have regulatory control which generally exceeds the usual port state control. In addition, certificates offer a method of control which saves much time in checking rigs.

Mr. I. Townsend Gault (Dalhousie Law School) cautioned against using Norwegian, British, and Australian offshore regulatory systems as models for Canada, since these were developed in particular political and economic environments which are not necessarily similar to those in Canada.

Mr. Townsend Gault expressed the opinion that deregulation of the offshore oil industry is premature. No one has yet examined the efficacy of regulations which today tend to focus on the quality of the machinery and not on the operation of it by individuals. Because this focus has not been solidly determined, the question of increasing or decreasing regulations is untimely.

Of concern also to Mr. Townsend Gault is the legal status of the enforcement of guidelines which are not regulations and which are sometimes incompatible with existing regulations. He disapproved of the use of the revocation of the operator's licence as the ultimate sanction and felt that it is more appropriate to "tidy up" and update the current set of regulations while at the same time avoiding the rush to create numerous new ones in the aftermath of the *Ocean Ranger*.

The lack of any criminal law jurisdiction over the Canadian offshore is another problem that Mr. Townsend Gault identified as being of concern and he criticized the inattention of the Federal Government to it. He said that the process of changing regulations in response to changing circumstances has always been slow but it can and should be hastened, and he outlined the problems encountered by the operators in complying with Flag State versus Coastal State requirements which are often not compatible. He referred to a move by the Law of the Sea Convention and the U.S. towards granting the Coastal State supremacy over Flag State jurisdiction, and suggested this approach should be considered by Canada as well.

Mr. Letalik spoke about the lack of effort by industry to learn from disasters which have occurred and to effect appropriate changes within the organizational structure of the industry. He cited the experience of the Japanese auto industry which, in order to improve quality control, reduced the number of management levels so that the implementation of production changes is never far removed from the decision makers. He wondered whether this approach had been considered by the oil industry, both on a company level and on a general, industry-wide level.

Mr. C. Bonke (CPA Offshore Operators Division) responded that the oil industry as a whole has displayed a very heavy commitment to safety, and each company implements this commitment through its own organizational structure. He said that the Offshore Operators Division of the Canadian Petroleum Association is a new development which resulted from changing conditions and which is an attempt to bring the management team closer to the actual operations. Mr. McIntosh agreed that industry everywhere is constantly scrutinizing and evaluating safety programs and practices, and that symposia are held, training procedures are upgraded, and safety awareness generally is in the forefront.

Mr. Manum indicated that Norway is about to introduce regulations on internal control

systems, which are intended to ensure that the top management people of a company are not too far removed from operations in the organizational structure of the company.

Mr K. Oakley (CPA Offshore Operators Division) reviewed the official policies of the industry on safety, and the measures which have been taken, often in full consultation with government, to enhance safety. While industry approves Canadian Coast Guard certification of marine personnel, it feels that standards for and certification of other rig personnel not now covered by the regulations should be the responsibility of industry, with review and input from government; a joint effort by operators and drilling contractors has already identified and described training qualifications and standards for MODU personnel. Mr. Oakley pointed to the industry-supported Petroleum Industry Training Service as the appropriate vehicle for carrying out this responsibility.

Mr. Oakley reminded participants that the offshore oil industry in eastern Canada is still in the exploration phase and forecasting the future use of rigs is risky. Because the region currently has twelve rigs operating, CPA does not subscribe to the use of a multi-purpose search and rescue vessel as the answer to the safety problem. The industry believes that properly equipped and manned standby/supply vessels and dedicated, industry-contracted helicopters are more effective in maximizing operational safety objectives. Mr. Oakley indicated that industry would by far prefer a user pay system, with fully trained SAR technicians, operated by the government. He felt that there has been and still is active cooperation between industry and government and referred to the recently-created Training Committee comprised of representatives from the Governments of Canada, Nova Scotia, and Newfoundland, and from industry. He also referred to the continuing cooperation amongst the operators themselves, who are constantly getting together to improve safety equipment, communications, training, and logistics.

Session Chairman J.E. Hodgetts concluded discussions by referring to the lack of debate by participants on the role of drilling contractors in all the systems and processes which were discussed, especially since they seem heavily involved in the actual implementation of regulations.

6

CONCLUDING

CONCLUDING

INTRODUCTION

As a conclusion to the Conference on Safety Offshore Eastern Canada, the Chairmen of each of the four Technical Sessions were requested to comment on the major issues identified in their respective areas during the Conference. These summarizing remarks were then followed by a final discussion session with participation from the floor.

The Conference was officially adjourned after closing remarks by Conference Chairman Dr. O.M. Solandt and a closing statement by the Chairman of the Royal Commission, Chief Justice The Honourable T.A. Hickman.

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CONCLUDING REMARKS

We are now at the end of a Conference that brought together a great deal of expertise to discuss various factors that are pertinent to safety of men and equipment offshore. I hope that the discussions have been useful to you and I think that perhaps bringing together this group in itself was very useful.

The subject matter presented in the Conference was logical in its order. On the first day we discussed the critical environmental factors and how they are input into design and the principles used in doing that. We talked about critical systems and the continuity of engineering responsibility. As a professional engineer, I believe that the profession must assume more responsibilities than they have in the past for the professional tasks that they are charged with doing. These factors are pretty well tied together in our knowledge of environment and our ability to design machines for it. We then heard a very lucid description of operator competence regarding systems. We talked about organization and management, which described the ability of men to work with machines, and it was then that I began to pick up a thread of a concern that I will come back to later. Following that we heard about escape and survival, and operations research as applied to rescue, or in other words, our ability to react to emergencies when things go wrong. And finally, we heard this morning comments from four people on regulatory systems.

I agree with and urge your attention to many of the points raised by Gordon Harrison in his paper "Perspectives on Safety". He made the point that we already have a good knowledge of the environmental factors, the selection of design criteria, safety factors, qualifications of designers and so on. I think it came through that, in general, our technology is pretty good, and it usually is not the cause of failure. Let me hasten to add, that does not mean we should lessen our efforts to improve environmental data and should certainly not decrease our design criteria. I think it does mean that we could look to other areas to achieve the most significant improvements in safety.

Perhaps I could list in point form factors which I think are important with respect to safety. First of all, a breakdown in safety is common even in the most regulated and the most sophisticated society. In most cases the cause of failure is not lack of technical knowledge but it is a lack of communication, continuity, and management. In other words, it seems to be a failure in the human to human interface. With respect to the man/machine interface, we must realize that in emergency situations the capability of a person to perform, even minimal tasks, may be limited. We have to make greater efforts to accommodate this factor. We need better methods to handle the mass of data that is being collected from many sta-

tions and many locations today. That data, which is in files that can not b retrieved, will not be much use.

I think that training may be the most cost effective way to spend our tim and money for better safety. One thing that came through, but I do not think tha anyone particularly addressed it, is the matter of language of regulation, of desigr of operation; in fact, the whole industry is becoming so complex and so full of jar gon that we are adding to our own problems. Just to give an example, the use c acronyms is now so prevalent with engineers and the bureaucracy, it must be ou way of getting even with the lawyers, whose language is rendered almost incom prehensible with big words and with their wherefore's and whereas's and the occa sional bit of Latin that is thrown in to avoid any possibility of clarity comin through. We are doing that, too, and we should get back to talking in plain Englis and try to avoid baffling people with science.

And finally, I think that we are making progress rapidly but the technology c today is also moving very rapidly. We are on the very frontiers of our geograph and our knowhow, so we cannot let up in our efforts. I would like to try and sum u what I have been saying by introducing you to FREDS, a Fairly Remote Exploratio Drilling System.

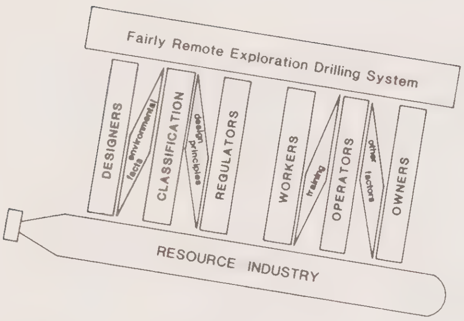
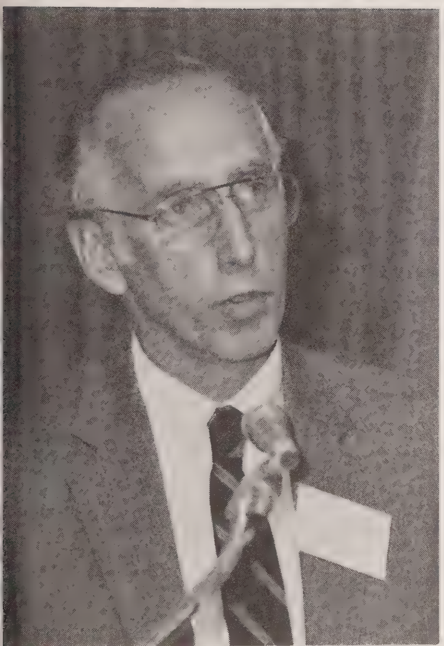


FIGURE 1 "FREDS"

FREDS is now listing because of incidents such as the *Ocean Ranger*. Mayb there is a little ballast in some of the wrong tanks and there are some extern forces of public and political pressure which are appropriately shown by that win reaction. FREDS main support comes from the lower pontoons, which are th resource industry, and the columns are the designers and classification people, th regulators, workers, operators, and owners. We strengthen the structure with th environmental knowledge, design principles, training and so on.

We had a very learned paper that told us that the weakest points in a struc ture like this are at the junctions of the various members. The individual membe are okay but we have to continue to improve them. The main problem is at th joints where we get these stress concentrations. Those main joints or tie-ins c various involved people and agencies, of course, are illustrated by the communic tion problems that occur. The best opportunity we have for improvement is t work on those connections to ensure that better communication and better tran fer of strength (information) is possible and we must strengthen the joint syste (communication) for better management. That is one of the points that Gordo Harrison was making.



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CONCLUDING REMARKS

The Tuesday morning session on man/machine interface was extremely interesting. The first portion related to operator competence in relation to critical systems technology, and I came to this Conference with a pre-conceived notion that I would be having to deal with problems regarding man's ability to accept and to cope with technology, as that is something that we are seeing elsewhere in society. Also, I thought we would be dealing with concerns about information overload, or operators being exposed to so much information that they have difficulty making appropriate choices. But the discussion I have heard has not borne that out although concerns were expressed about, I believe the expression was "moron technology" and the degree of danger of repetitive training leading to complacency.

Dr. Foley graphically illustrated the flaws in our every-day designs and I am sure that each one of us has experienced the frustration from such lack of common sense. Dr. Haakonson gave examples of the increasing incidence of jobs where, in his terms, there are long periods of boredom, interspersed with short periods of absolute terror. Technology, unfortunately, is leading us more and more in that direction in many professions. We run increasingly the danger of being lulled into complacency and boredom because of technology and we must in the words of one of the participants in my panel, "pay attention to incidents to stop them from becoming accidents." Technology is making us complacent to the point of where we are not paying adequate attention to incidents.

My reaction to the first portion of the session, operator competence, was that I heard concerns about too much technology, too much simplification of tasks, yet I heard no evidence that we have reached that stage of man/machine interface in the offshore region. This leads me to my conclusion on this subject, and I must make comparisons to high technology industries and the nuclear industry. I have seen very excellent applications of high technology in the offshore of bringing a rig onsite and maintaining it properly over the hole, and of well logging and interpretation. I have not heard or seen evidence of any dramatic increase in the use of high technology in the actual drilling operation itself onboard – of employing high technology to the optimum. I do not mean the maximum, I mean the optimum.

Let me take the most extreme example, and here is where I must make a comparison. The extreme example on the platform is the activation of blowout preventers. I could liken that action to a problem in a nuclear plant where there is a loss of coolant.

Without human involvement whatsoever, the emergency core cooling system is activated by a machine and the plant is shut down by a machine. There is no human override involved whatsoever. We have all watched the space shuttles go down to the last two seconds and the machine shuts down without a human pushing a button, because of the lack of performance, quite often, of some relatively minor part of the total makeup. So when you compare that, you can see my confusion about what I understand is the case when you lose mud pressure in a hole being drilled and there is high potential of leading to a blowout; there is no electronically monitored display and there is no automatic action by the machine to activate the blowout preventers, not even one that gives you ten seconds for manual override. My question to the learned audience is, why not? Given the consequences of such problems in a drilling operation, both human and environmental, why is that we still have the hands-on attitude of the human operator at that point in time? Are we not inviting the obvious consequences of "fixations" or "cognitive locking" by humans, which happens in extreme stress? Obviously the attitude of the operator is that it cannot happen, or it can be fixed in time.

Mr. Hielm, on my panel, observed the problems with a surplus of confidence by people, or the human tendency to "tie solution to situation, rather than situation to solution." Today's modern machines are excellent in tying situations to solutions and presenting solutions very, very quickly to the human being. So, why has not the ability of today's technology to analyze a situation and suggest a solution been used in this very critical operation?

The offshore activity draws on two very interesting sectors of the economy: the marine industry with its long history and tradition, one of acceptance of the perils that are out there because that is part of the job, a degree of fatalism that a speaker mentioned yesterday; and the petroleum industry which is much newer and brings with it an element of feeling of the frontier where it has always worked with very much a degree of individualism and hands-on attitude. I suppose there have been many studies about that mix of our inheritances in the offshore operation. It appears we are dealing with an emotion, but do not quite have a true mix as yet. So my observation on the first part of the session is that I do have doubts that this industry has used the rapid advance in technology to its optimum capacity in all its aspects.

The second portion of the session dealt with organization and management. Mr. McGrath's paper was an interesting mix of satisfaction with the existing organizational and management structures, but at the same time it expressed concern with such things as "one person should be clearly in command at all times." It would appear that there are situations where this is not the case, and it would also appear that some in the industry defend that on the basis that change-over in command takes place by an official sign-over procedure. In normal circumstances that might be all right, but surely in the case of an emergency, especially where there may be somewhat different objectives, that is not an acceptable situation; I detected a strong view that, in all cases one person must have final authority at all times.

Mr. McGrath's paper also initiated discussion on the lack of formalized qualification requirements for key positions on board the drilling unit. For the uninitiated like me, the lack of such certification came as a shock. Much has been said about the hostile nature of the environment within which the industry must work and yet we lack an agreed standard of training for those that we send out into that environment. I detected here a unanimous view that certification by a single authority is essential and I do hope that our small "p" and capital "P" politics make that possible.

To come back to the man/machine interface, we have an opportunity in this country to use modern technology. For example, Canada is a leader in simulation

technology. We use it, of course, extensively for air crew training, and simulators are being developed now for small private planes to reduce the amount of time required in the air itself. I heard the argument presented that each drilling rig is different, but simulators can at least give you that 80 to 90% total feeling of being involved with the rig or being in the ballast room, and surely that is something we should strive for in our certification process.

One final observation on my panel discussion on the question about reporting systems for items such as accidents or incidents. Mr. McGrath's presentation stated that "reporting of incidents is in a transition stage and is subject to individual judgement due to the lack of a clear indication of what incidents must be reported. It is expected that it will be worked out over time." Compare that to the earlier admonition of Dr. Haakonson on the same panel when he said, "Pay attention to incidents, stop them from becoming accidents." Clearly, something must be done in this area. I must once again make a comparison to the nuclear industry where all incidents must be reported, where it is not left to the judgement of the individual concerned. They can be serious incidents or accidents, or they can be trivial ones; they can involve the nuclear component of the operation or the non-nuclear component, but they must be reported. This procedure provides a vital record of what is happening in that operation. I think the discussion has pointed out a clear need for action in this area.

Finally Mr. Chairman, to put my Natural Sciences and Engineering Research Council (NSERC) hat on, I must say my Council has active programs to promote research, and has increased the research effort involving industry and university. We have launched programs recently to which I have seen a significant response from the high tech industry, the forest industry and even the mining industry, but I have yet to see any significant response from the petroleum industry. I would have thought that I would have seen it from Memorial and other places where we do have significant engineering and advanced technology experience. I have seen nothing but a very fertile area for research and development, and I must disagree strongly with the comment that was made this morning, that the accidents we have heard about could not have been prevented by advanced technology, that it is more training that is required. It is not a case of one or the other, it is a case of both.

Dr. A.J. Mooradian
Senior Vice-President
Atomic Energy of Canada Limited
Chairman
Session Four
Emergencies

CONCLUDING REMARKS

I am going to comment on two areas: 1) the session I chaired very briefly, and 2) I would like to give you an overview of some of the important pieces of this Conference. You have heard from a body of experts that has a tremendous, mature and deep knowledge of the subject, and it might help to have some of their ideas fortified by someone from the outside. My background is in the nuclear development business, not in the nuclear regulation business, so you should keep that in mind as you hear my comments.

First, on the question of escape and survival, we have heard that there is plenty of room for improvement, and that it is a tremendously hostile environment which is likely to respond to concerted effort. We were given some good examples and good approaches on how to go at it and at the same time we were told about the institutional sorts of constraint possibilities and the competitive pressures, which operate on the motivation to proceed. However, I cannot really accept any of these as a real inhibition for action because what I detected is a uniform and sincere will to proceed to improve this area.

How can technology help? I would like to address the Commissioners specifically in an area that I know something about. You are not being addressed by the most brilliant technologist in Canada, but I can tell you that technology is hard. Our legal friends are very generous; they think we can do almost anything with science and engineering, that all we have to do is throw in the resources, throw in the effort and just release this tremendous intellectual capacity to get a result. There is an illusion that science proceeds very fast, that innovations proceed very fast. Science and technology, particularly in conservative areas, such as the ones that you are addressing, are a hard, tough business. My suspicion is that if we are going to get a new lifeboat system, it will take a significant effort, that this is no $100,000 sort of international game. This is a several million dollar, several year game that is going to require on-site proved demonstration, redemonstration, and qualification, all down the line, even if it is to be only an engineering type of solution. This area deserves attention, and it undoubtedly will respond, but it will not respond to a half-hearted effort that is based on a preconceived idea that it is a small job. It is a big job. It is as big a job as small reactors. It is easy to build a power plant, but it is a heck of a job to put one in an automobile.

On the rescue side we have also heard that this is more likely to respond to man-to-man interfaces than technology interfaces, that much of the technologies in place require organization. That is all I would like to say about the particular session I chaired.

I would like now to say a few words about my perception of the whole Conference. I have to start with our keynote speaker. I had some difficulty with two particular points that he brought out. The first was the indication that the private sector can handle this job alone. In my job I have interfaced with the private sector, the public sector, and the academic sector, and no one of them has a corner on responsibility, no one has a corner on the sense of motivation or of accountability, and no one has a corner on response capacity. It requires the marriage of all of these, and that is the most likely situation we are going to encounter. It is not helpful to isolate them.

The second point on which I disagreed is the treatment of accountability. I find that Chief Executive Officers fail with the same monotonous regularity as the rest of us. In fact, in some environments, they fail somewhat faster. Chief Executive Officers do not have a corner on perfection, so a fully accountable CEO can certainly lead to a fully accountable catastrophe, which is, nevertheless, a catastrophe. Accountability does work and it is an important aspect of management. It works when responsible people have something to respond to, or for which they can be held responsible. They need signals and part of the difficulty in developing a safety regime is developing the signal mechanisms.

I think this industry has a special problem because it brings two cultures together, the drilling culture and the maritime culture. The maritime culture is a thousand years old, with a tremendous tradition and conservatism in addressing catastrophic types of events where tens, twenties and possibly even hundreds of people are at stake from the given mistake. The drilling culture is not any less responsible, but it has been brought up in a different regime. It is a production type of regime, an industrial regime. In the nuclear industry we set up a regime which lets us look at every incident and we understand it. We do not shut our plant down, but we examine it until we understand it, and we work in a safety administrative zone. We are in a continual dialogue of safety in this safety administrative zone, and it allows us to concentrate on our safety within that area.

If you ignore the minor incidents, you do not get this kind of interesting dialogue throughout the whole of an operation. It is a continuing kind of dynamic thing, and everybody has a common aim; the operators, the owners, and the workers all want a safe plant. It is not that tough. In the development of regulations you have to make it easy, not punitive, for people to report.

In the nuclear industry, I think the most important attitude we bring to safety is humility. It is important to know what you know and even more important to know what you do not know. One can then address the minor incidents and extract from them the maximum benefit in attitudes.

Dr. J.E. Hodgetts
Professor Emeritus
University of Toronto
Chairman
Session Five
Regulatory Systems

CONCLUDING REMARKS

We were instructed as Chairmen to produce, on this last occasion, a kind of steely-eyed view of the proceedings. I can say that in every session I have had more fully confirmed an earlier previous impression that the particular arena of offshore exploratory drilling affords one of the most complicated venues in which public policy, as it relates to safety, has to be worked out. As a social scientist watching these proceedings, I observed the scientist interface with the engineer as the relationship between environment and design was confronted, and I found what seemed to me to be a fascinating tension between the literally inexhaustable appetite of the scientist for the accumulation of yet more accurate data, and the immediacy of the demand of the design engineer for hard facts.

With my particular concern with the regulatory side of this, I wonder about the relevance of this tension to the regulatory process. I suspect that the engineers feel that the scientists' demands for more research and more data may encourage overkill on the part of rather nervous regulators looking over their shoulders to the implications of what is the very significant feature, the 100-year wave, or the 100-year wind. That is one tension that was reflected in some of the concerns expressed this morning on the regulatory side.

In the discussion of the man/machine interface, I saw another sort of tension surfacing between two schools of engineering: one that emphasizes the separation of the man and the machine; and the other view, which views man as a machine with no interface at all. Again, the implications for public regulatory policy are still not clear to me, but perhaps there may be the root of the assertion that you cannot regulate against the frailties of human nature. Nevertheless, I suspect that it is not all that clear whether the regulation of the machine, the components of the machine and its requirements can help the human overcome his frailties. We in fact talk about that when we talk about the capacity of the machine to reduce the capability gap that one finds as a consequence of human limitations.

Similarly, as we move from concern for the individual human being to the human being acting as a system for productivity, attention shifts to organization management structures in which regulation imposes or insists upon standards of performance and qualifications for the key managerial personnel on the basis that such requirements can in turn improve the productivity of human beings. This is probably just an awkward way of raising the question of the relationship between training and regulation, and the further question of calculating whether compliance with regulations of any sort in this area can be achieved. Or indeed, the further question of who, in the end, should be responsible for imposing standards, the

operators, the industry, or governments acting in the name of the elusive "public interest", which I have not heard anyone refer to in this Conference.

The discussion in the third Session was really warming up toward the end, and a question was posed concerning the conflicting priority on a drill rig because of the different perceptions entertained by operator, contractor and regulator, and the effect of this conflict on the response of the crew. Now, I put that beside the rather interesting and spontaneous eruption when the apparently evil word of "union" was introduced this morning in conjunction with the question of whether the unions have had input into this Conference. A more mutual way of introducing that, without the presumed threat that is contained in the word "unions", would be to ask if there is any input by workers with respect to the regulatory process.

In Session Four, I perceived the tension or frustration created for the engineering designer facing regulators, particularly international regulators. Yet, as I understood that discussion about lifeboats and the introduction of more innovative techniques with respect to lifeboats, it sounded to me that, unless you did handle this through the international regulatory route with international agreement, there would be no disposition on the part of industry to incur the financial sacrifice required.

Finally, I want to come back to accountability. The word "accountability" was in fact seldom used in these Sessions, but a lot was said in terms of the word "responsibility". It is a loaded word that can be badly used, because it has quite a variety of meanings. I did hear, for example, nearly every participant claiming that they wanted more of this thing called responsibility. From our keynote speaker on through, industry was asking for more responsibility, the classification societies said they had a lot of it and the regulatory agencies took second place to no one in their claims for asserting this responsibility. All of these claimants are defining responsibility in one of two ways. The regulatory agencies are saying: we are responsible because this is our duty, and we are responsible for regulating legislative acts. And industry is saying: we are responsible people without being obliged by any regulation, and we are so at great personal expense; we have developed a unparallelled training program.

Throughout this Session I only twice heard a reference to responsibility in what I consider to be any gutsy sense of the term. One was an historic reference to that poor benighted engineer who died of shame because he was held personally accountable for the Tay Bridge collapse. That was the one key reference to accountability about which we should really be concerned. The other came from a drill rig owner/operator who, in referring to his being out on that rig on the high seas, said he really felt responsible for his people and for what was going on out there. Otherwise, anything less gets to be pure double talk and is falling into the same disrepute that seems to be developing for this notion of Ministerial responsibility. Yes, the Minister says, we are responsible in accordance with good constitutional doctrine. So what? Do they fall by the way? Do they resign? Indeed not. The Opposition goes back and licks its wounds and hopes that it can get in and apply the same interpretation of the doctrine of Ministerial responsibility.

So when you do accept responsibilty, is that being accountable in any real sense of the term? If responsibility viewed as accountability means anything, it means either that I am responsible to myself in the Shakespearian sense "to thine own self be true", or perhaps I would modify it to say "to thine own professional code of ethics be true"; or else that, yes, I have been assigned this duty and I am answerable, not in this instance to myself, but to someone out there, for the proper performance of that duty that has been imposed upon me and which I have accepted. I am prepared to take the consequences if it can be demonstrated that I have violated the commission of trust which has been imposed upon me.

Accountability or responsibility used in that sense is simply a matter of being

the discipline for the actors. This is what this whole exercise is about. People are not paying attention because nobody is accountable in that sense. Sure, all had responsibility, all had duties, but where was the payoff in terms of being genuinely accountable? Why would people be forced to report the incident if there was no pressure in the system on them?

I like to use my old colleague and mentor, Alec Cory's story which he used to tell to his freshman class when they came in. It is the best demonstration of what I mean by accountability and I will leave you with this thought because I think one cannot dispense this notion of accountability as I am giving it. A mule trainer was brought in by the farmer to train a mule and his first action was to go over and take a board off the fence and proceed to beat the poor beast about the head. The farmer protested, "What sort of mule trainer are you?" The mule trainer replied, "The first principle of mule training is that you have got to get their attention." Now that is what accountability is all about. Get their attention and that applies from top to bottom of the system and if there is any break in that linkage, in that long chain of accountability, then all hell can break loose.

Summary of General Discussion

Dr. R.B. Wardlaw (NRC) opened discussions by noting that the Conference's Technical Sessions identified numerous gaps in the technological data base being used by the offshore industry, and that it also became evident that the industry has very little ongoing scientific research. This is so despite efforts of the National Research Council to establish an environment which encourages research either through funding or the provision of technical support. Dr. Wardlaw felt that regulatory or codewriting bodies should play a leadership role in encouraging this necessary research, since these bodies interact positively with the scientific community in both industry and academia.

He advised the Conference that Canada already has a precedent for such an approach in its National Building Code which is thought to be one of the most progressive and responsive building codes in the world. It was suggested that this Code and the methods and procedures used to keep it current and accurate would be a suitable model for the establishment of a progressive and dynamic code for the offshore industry.

Session Chairman Mr. R.A. Hemstock emphasized, however, that initiative for research must originate with the industry, and not with government, in order to achieve satisfactory results. Nevertheless, industry should take advantage of the research opportunities, funds and support made available, and the offshore industry has not done so in the past.

The question of achieving accountability, whether in government, in industry, or on rigs, generated much discussion. Session Chairman A.J. Mooradian, citing the experiences of the nuclear industry, described the use of a "signal system", first to identify and then to resolve problems. The nuclear industry treats all incidents as serious and, therefore, worthy of recording and investigating. That includes events which are well within the non-catastrophic range. This reporting system spreads levels of accountability throughout the whole infrastructure of an organization, from the chief executive officer to the worker in the field, and provides data to be used towards the prevention of incidents which may be catastrophic. In the offshore industry, with its mating of marine and industrial cultures, it is imperative to make accountability a state of continuing operation. This may be achieved by setting up the criteria based on figures which are already available, and by developing an information system that allows everybody to participate in improvement of the industry.

Session Chairman Dr. J.E. Hodgetts disagreed with the establishment of a "system" of accountability and preferred an approach which makes accountability a collaborative venture between industry and regulatory authorities, with both groups having a precise perception of what each is supposed to be doing for which it is to be accountable. The flow of information would be an important aspect of this approach. In addition, no method of assuring accountability is workable without the attention and awareness of the legislative body which, in our parliamentary system, has the ultimate authority.

Mr. Norman Letalik (Dalhousie Ocean Studies Program) suggested that, because politicians have created great expectations in the general public from the oil industry, the public tends to confer accountability on government. Consequently, government aims at complete control over all facets of the offshore industry, since they feel that the public will hold them accountable.

Session Chairman Dr. J.E. Hodgetts responded to this suggestion with the comment that government creates policies on energy and establishes crown corporations to manage and administer them, and that this places them squarely in a

position which makes it difficult for the public mind to dissociate government from the question of accountability.

Dr. E. Gold (Dalhousie Ocean Studies Program) felt that accountability should not be confined to events following an incident; there should be more emphasis on accountability for the prevention of incidents. In this light, it does not seem proper from an accountability point of view to allow rigs similar to the *Ocean Ranger* to continue operation. And yet, no one in the offshore industry, either on the government or the industry side, has taken the responsibility to recall such rigs. This is often done in the aviation industry, where at times whole series of aircraft are grounded until safety conditions are restored.

Dr. T.D. Petty (ODECO Engineers, Inc.) made lengthy comment about the role of rules and compliance with them in the achievement of safe design. He referred to the *Ocean Ranger* which was built to compliance with existing rules but which sank in conditions far less than those for which it was designed. That such an event could happen indicates that design and construction rules are an inadequate assurance of safety, despite the other weaknesses (such as lack of documentation and improper training) which are said to have contributed to the loss of the *Ocean Ranger*.

Dr. Petty was specific in his criticism of the rules which permitted the design of the *Ocean Ranger* as an unsafe rig. In 1973, classification societies, at insistence from industry, relaxed stability criteria for semisubmersibles and thereby decreased the inherent margin of safety which had been in existence up to that time. This resulted in too much dependence on gadgetry, procedures, and people for adequate safety. Furthermore, present rules allow a semisubmersible to be designed so that when the allowable KG is being determined, it may heel to its angle of downflooding in an assumed calm water condition. Calm water is an unrealistic condition in 70 or 100 knot winds.

The angle of downflooding under the calm conditions assumed is normally found to be in excess of 20 degrees. Dr. Petty also stressed that when a rig is heeled to 20 degrees, a condition allowed by the rules, it is highly unlikely that a crew could perform any effective work, regardless of the positive attributes of training in overcoming stress under emergency conditions. Useful work is not likely to be effective beyond 12 degrees.

The rules in effect today allow a designer to assume various cases of damage with only a 50 knot wind load (again in the unrealistic calm water), and this may be applied to the U.S. Outer Continental Shelf, the U.K. North Sea, and to offshore Canada. In addition, a designer is permitted to allow the deck to become submersed and awash at the angle of downflooding, without being required to ensure that the deck is structurally able to withstand the forces imposed by sea waves driven by 100, 70, or even 50 knot winds. A design which allows this to be acceptable has severe implications for the major problems already encountered in the launching of lifeboats and with evacuation systems generally.

In a plea to re-address the fundamentals, Dr. Petty urged the Royal Commission to regain the pre-1973 margin of safety in rig design and to limit, by design, allowable heel and list angles in the various cases of damage which are assumed in the stability calculations. He emphasized that these calculations should require the consideration of reasonable wind speeds and the resultant forces that can be expected in the environment. These measures would increase the probability of rig survival and, in turn, would increase the resiliency of the rig to absorb human error.

The suggestions made by Dr. Petty were endorsed by Mr. J. Hornsby (CCG

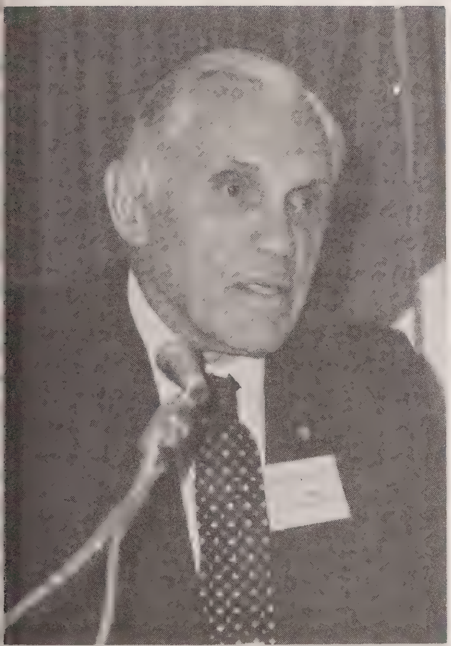
Ship Safety Branch) but Mr. Hornsby reminded the Conference that to follow them would result in the "grandfathering" of nearly all existing rigs because they would not meet these revised standards. Mr. Hornsby advocated that, all things considered, it is the flag state and those who permit the drilling operations who are responsible and accountable.

Dr. Gold noted with interest the hostile reaction to the suggestion that the offshore industry should be unionized, and commented that the cited example of experiences in Australia was not one of good management and labour relations. He said that there is a role for labour, whether organized or not, and there are many examples worldwide where organized labour has had a responsible and effective input, particularly on the safety side of the industry. This is an aspect which requires further development because the industry as a rule tolerates little criticism from its employees.

Mr. J. Hielm (Elf Aquitaine Norge) stated that in Norway the law requires that employees elect a representative to the safety committee of a rig, and, of course, where there is a union, this representative would obviously be a union member. It is important to stress, however, that he acts as the representative of the employees and not of the union. This representative is required to be thoroughly familiar with employee responsibilities and obligations under the law. Also, inspections by the regulatory authorities include private interviews with employees, which provide the opportunity for both structured questions on safety and free discussion on matters of concern to the employee.

Mr. R. Fodchuk (Shell Canada) reported that at Shell Canada the safety representative does not come from the ranks of the employees but is someone independent of the rig's management. This person also interviews employees following any incident (such as was done following the *Vinland* blowout at Uniacke G-72) in order to obtain useful feedback on emergency procedures from the employees' point of view. Each rig also holds a weekly safety meeting which all employees are requested to attend, and this provides another form of communication. Mr. Fodchuk also stated that Shell Canada has very formalized procedures for the reporting of all incidents, even when the incidents fall under the control of a sub-contractor. Furthermore, industry is attempting to avoid variances in reporting between the operators and the drilling contractors by standardized reporting to the Offshore Operators Division of the Canadian Petroleum Association in Calgary.

Mr. J. Gow (Mobil Oil Canada) described Mobil's safety committees which comprise three management people and three workers, with all workers being given the opportunity to serve on the safety committee at some point. These committees examine their respective rigs for safety deficiencies, have a follow-up mechanism to control the deficiencies, and report, in Newfoundland to Occupational Health and Safety, what deficiencies are found, how they are rectified and when. Mobil is proud that these committees have been established prior to any regulatory requirement.



Dr. O.M. Solandt
Conference Chairman

CLOSING REMARKS

By way of introduction I will recite a little notice that a friend of mine used to have over the desk in his office. In large letters, it said, "If I seem to be confused, it is only because I am." I knew that making these concluding remarks would be a difficult task, but I had not appreciated until today how difficult it was going to be. I prepared my notes last night and now almost everything that I wrote has been said during the morning. The few remaining *bon mots* that I had up my sleeve have been stolen by this final panel. I will still attempt to give some concluding remarks. I am not going to try to make a systematic overview of the whole meeting; I will just try to touch on a few highlights and especially on areas where it seems to me the Commission may wish to give further consideration with the possibility of finding material for recommendations.

In general, it seems to me that the Conference has been a success. The Chief Justice will tell you more in his concluding remarks as to the views of the Commission, which are the ones that really matter. The purpose of the Conference was to expose the Commission to the opinions of experts and they have certainly been exposed. It has on the whole been an open discussion. If we could go on for a few more days it would become even more open and more lively. There is every indication that people are beginning to feel more relaxed with each other and are ready to say what they think. There has been a fair amount of repetition of the conventional wisdom and an occasional covering of positions, but for a Conference in which there have been so many diverse interests represented, it has gone extremely well.

Gordon Harrison's keynote address found very little response in the earlier parts of the Conference but has been mentioned several times recently. It is a great pity that he is not still here to try to tell us exactly what he did mean, because there have been many interpretations of what he did say. The general message that I got out of it was that there have to be absolutely clear lines of command, responsibility and authority at every level in such a complex system, so that no one is ever in any doubt as to where the orders come from, and nobody who gives orders is in any doubt as to whether he is responsible for the result.

Turning now to some of the specific sessions, the one on the environment was interesting and useful. It highlighted the fact that we badly need more data, that we certainly need more measurement of wind, waves, and current at the same time and in the same place, and that the forecasting, particularly on the Grand Banks, would probably be substantially improved by the use of buoys to give more weather observations. It was not mentioned in the session, but I think it is worth

underlining here that while the forecasting and weather information seem adequate in the exploration phase, it will be very important and valuable to have much better forecasting during the production phase. Clearly, the greatest need from the environmental point of view is for somebody to turn up reliable records of wave heights dating back to 1880, but that is unlikely to happen; that might give some real clues as to the size of the 100-year wave!

We heard in some admirable papers on structure and design about analytical methods both for general structural strength and fatigue life. It was clear that the designers need from the environmentalists far more than just the height of the 100-year wave. They need wave spectra, and information about wind directions and wind effects on the structure in much more complex ways. It was particularly interesting to find that the experts on structure disagreed quite sharply on many important points, illustrating again that this is an art and not entirely a science.

Offshore safety, as evidenced by the interaction between the environmental information and structural design, is a classic example of the interface between science and engineering. A conservative scientist, if asked, "Do we really know enough about the environment offshore on the Grand Banks to design a completely safe and reliable drill rig?", if he were frank about it, would reply, "No, we do not really have enough information. Give us another thirty or forty years' observations and come back and we will tell you exactly for what conditions you ought to design." The engineer says, "Fine, but we want to drill today. So, we will cautiously begin drilling first in sheltered waters, using all the scientific knowledge that we can get. As we advance into deeper and more difficult situations, we will try to spur the scientists into giving us a little more help, and gradually we will be able to conquer the most difficult areas."

This approach has worked remarkably well, as it traditionally has with engineering, and it should not be either belittled or mistrusted. What we need is an increasing cooperation between the scientist and the engineer so that the scientist can focus his research more directly toward the things that the engineer needs to know for the future. And again let us not think that we have come to the end of the evolution of offshore drilling structures. We only have to think of the challenges that face the engineering community for the production structures that will be needed offshore on the Grand Banks and even more in Labrador. So, this process of evolution, the interaction between science and engineering must be pushed ahead as rapidly as we can afford. But in spite of what I have said, it is necessary to underline the fact that, even off Newfoundland and Labrador, offshore drilling is by no means one of man's most hazardous occupations. It is relatively safe, but can be made safer.

We had very interesting presentations on man/machine interfaces and discussions about the importance of adapting the job to the operator, not trying to adapt the operator to the job. This is clearly something that was needed in the case of the *Ocean Ranger*. I am not sure that it is needed now, as I have not been on any drill rigs recently or seen the latest in ballast control systems, but there is clearly no great problem in designing a ballast control system that will suit the general run of operators that are available. The same is true of most of the jobs on drill rigs. They are not at the limit of human capability, but they are ones where performance can be substantially improved by better attention to the man/machine interface, probably even more at the level of the interplay of the crew with the rig as a whole, and particularly in some specific fields like evacuation. The problems of providing not only the lifeboat or other improved mechanism for leaving the rig, but ensuring access to the embarkation points and ease of embarkation, of deciding in advance who will be in charge of the lifeboats, who will be responsible for giving the warnings? All this is part of the organization of what I would call the man/machine interface at this higher level.

Nearly all seemed to agree, and this was remarkable, on the need for a single commander, to have the same person in charge all the time. At many times it is obvious that whoever is in charge of the drilling side, is the dominant one. There was a difference of opinion as to whether it is easier to train an experienced toolpush to be a master mariner or whether it is easier to train a master mariner to be a toolpush. This is an argument that I am sure will go on for a long time, but in the meantime, it seems quite possible that some way can be found of ensuring that the man who is in charge is well qualified and can become the visible leader to the whole team at all times. It is particularly important not to have a transition in times of emergency.

On the hardware side of escape and survival, the discussion was extremely interesting and on the whole reassuring. The discussion indicated that, if enough effort is put into the problem and the effort must be substantial, as Dr. Mooradian pointed out, but not astronomical, not at all outside the limits of what should be available, it should be possible to come up with a satisfactory solution that could be widely adopted within a few years. What is needed is to make a systematic approach to this problem: writing down the objectives and characteristics of an effective escape system, thinking of all the solutions, having them developed by those who support them to the point for proposal, choosing a few, and funding, probably through a competition, people to get them busy working at it. These sorts of escape mechanisms should never be needed on oil rigs but they have got to be there and they have got to be things which are known to work and in which everybody has confidence. I, myself have a weakness for Colonel Brooks' ejection mechanism. I think it might be very effective and really rather pleasant, more pleasant probably than any of the free fall lifeboats, but, of course, pleasure is not what one is seeking in an escape device.

It was interesting to hear the unanimity about the problems of immersion suits. That is another one that should be attacked very quickly and solved. It will never be totally solved, but at least a better solution should be found fairly quickly.

The discussions on operations research, in relation to search and rescue, were very interesting, and came to a pretty straightforward conclusion which is about the same conclusion that both the U.K. and Norway reached some time ago. The conclusion is that the rescue system needed for offshore drill rigs is specialized and that an ordinary national search and rescue system is not designed to respond to their needs, nor would it be wise to try to distort the system in order to meet their needs. It is far better to add to the search and rescue system an element that is specially tailored for meeting the needs of the offshore rigs. This element should be integrated into the main system so that it can be used for other incidents in the area and can help to support rescue efforts in other areas. The lines along which it should be designed were well outlined. There was, I thought at one time, a little argument as to who was going to pay for it, but it sounds as if industry is willing to, if not pay, at least contribute quite substantially. So, that again, would seem to me to be a soluble problem.

In many ways the most important general lesson that has come out of the Conference is that Canada is just now in a great position to make its handling of offshore activities and their regulation a model for the world. In saying this, I do not mean that we are a lot smarter than other people; I just mean that we are coming along at a time when other people have wrestled with and successfully solved a good many of the worst problems, so that we, if we are smart, can pick up where they're at and add the necessary improvements to meet our own peculiar conditions, both political and climatic. With any reasonably good handling of our opportunity, we can really have an excellent system in operation quite soon.

You have heard about the present situation, about the complexities of the organizational structure, about the problems between Federal and Provincial Gov-

ernments, the relationship between COGLA and the Coast Guard and so on, but as you have also heard, these relationships are pretty good. Everybody is poised and ready to try to step in and do a good job. I will not attempt to outline a solution which would seem to me to be appropriate, except to suggest that the experience of Britain with OFINTAC, the Offshore Installations Technical Advisory Committee, seems to have been extremely good. It could be adapted as a model for an institutional structure in Canada. One of the important features of OFINTAC is that it brought together the combined technical expertise within government to interact with industry, and then presented its recommendations for public debate. I see an organization of this kind being set up not just to get a good regulatory mechanism in position now, but to keep the actions of the regulatory mechanism continually adapted to the needs of the time and even be looking ahead to see what is coming so that it can be prepared. To help achieve this, there should be an input from research so that research people can tell the regulators what they think is likely to happen and can also try to find the answers that appear to be needed by practical developments.

The most important thing that can happen in the near future is a rationalization of our institutions for regulation offshore along the lines I have roughly outlined, so that Canada can take advantage of this magnificant opportunity that is presented now. I use the term "regulation" here very loosely to indicate control. I was much impressed that when the two sides argued about regulation and about how much or how little there should be, that really they were not very far apart. They are both talking about the same kind of thing; you should not attempt to regulate every detail but some things just must be regulated very firmly and very strictly, and some of them in great detail, whereas others should be flexible. I think that common sense will prevail and that we can reach a good conclusion.

We should not overlook in this process the fact that we are seeking to bring together two different subcultures, the maritime subculture and the offshore drilling subculture. They really are very different. The maritime side, with its long history is still somewhat affected by tradition, and I say somewhat, because the people you meet nowadays in the Coast Guard are not the old-fashioned master mariner of the stereotype of 50 years ago. They are pretty sharp young guys who know what is going on, and the possibility of getting the two sides to see each other's point of view has never been better. I am just mentioning it to point out that when an oil man starts to talk to a master mariner and he does not understand him immediately, you should not think that either of them is stupid. Just keep talking for a little while, and you will begin to understand that each probably knows much about the other's job.

I will stop at this point on a happy note. Canada is at the beginning of a great stage in offshore activity. I hope that we will continue to keep an international outlook in this field as exemplified by this Conference, and that we should feel that our colleagues in Norway, Britain, the United States and many other parts of the world are friends who are pushing ahead in a joint international effort; that we will not specialize our regulations or other activities in Canada any more than is needed to solve our own special problems such as ice. Offshore oil exploration and production can be one of the most exciting and successful areas of scientific, professional and especially economic activity in eastern Canada and, in fact, throughout Canada.

Chief Justice
The Honourable T. Alexander Hickman
Commission Chairman

CLOSING REMARKS

When I opened this International Conference on Safety Offshore Eastern Canada, I expressed the hope there would be uninhibited dialogue between those in attendance. I have no hesitancy in saying that my hopes and expectations have been far exceeded by the obviously expert and responsible contribution of those who have participated during the past three days. You were invited to this Conference, not as representatives of particular segments of society, but rather because of your experience or expertise in the vital question of safety particularly as it relates to offshore eastern Canada. The comments and questions put by knowledgeable persons from many parts of the world have been frank, often provocative, but made in an atmosphere of genuine concern rather than irresponsible confrontation, which is precisely what the Commission asked of all of you.

It was recognized by the Commission, very early in our deliberations, that to discharge our mandate properly we would have to look to the world community for help, as the offshore oil and gas industry, while somewhat young when measured against the history of industrial development generally, had far more experience in other parts of the world than could be found in Canada where, comparatively speaking, the industry is still in its infancy. It is equally clear that recommendations which fail to take into account the international flavour of this particular industry will not be credible. As a consequence, we consider it most helpful to our task to have been able to listen to such open international dialogue between persons who possess detailed knowledge and experience in the offshore oil and gas industry. I have been encouraged by the many comments and suggestions from those in attendance that every two years there should be a conference of this kind in one of the countries represented here. While the Commission's work will be finished long before that time we may, in the future, be able to look back on this International Symposium as a small but significant step along the desirable path of world co-operation in this area of industrial development.

The excellent papers which have been presented and the learned discussions which have taken place will, over the next few months, be carefully scrutinized by the Commission as an integral part of our public consultation process. In that context, I repeat what was said earlier today, that anyone wishing to make further observations or comment on all or any of the matters discussed at this conference or indeed other areas of concern, which you may deem relevant to the Commission's mandate, please do not hesitate to write and let us have the benefit of your opinion.

This Royal Commission stands very much indebted to those who prepared

and presented such excellent papers. We are equally grateful to those who chaired the sessions and those who acted as discussants; we have been treated to a world-class performance by all of these people. I thank, as well, all of you who accepted our invitation to attend and who came from various parts of the world as well as from other parts of Canada to participate; your comments and often provocative interventions contributed a great deal to what I modestly believe has been a successful gathering.

The work of Dr. Omond Solandt, as general Conference Chairman, has been most effective indeed and I thank him for a job well done. The Conference Vice-Chairman, Dr. Ross Peters, has discharged his responsibilities with the kind of efficiency and zeal that we have grown to expect from our Dean of Engineering and I know I voice your sentiments, as well as those of the Commission, when I express to him our sincere gratitude for his efforts and co-operation. I extend to Dr. Leslie Harris, President of Memorial University of Newfoundland, and the faculty and staff of the University, including the competent staff of the R. Gushue Dining Hall, our thanks for their co-operation in making this Conference facility as well as other University facilities available to us.

I would be remiss indeed if I failed to express the gratitude of all members of the Commission to our Commission Staff, all of whom have worked long hours preparing for and seeing to it that the Conference ran smoothly and efficiently. They are a super group of persons.

On Tuesday, I commended the Honourable Gordon Winter and his Conference Committee for their efforts in organizing this event. Their choice of speakers and participants has vindicated the trust we placed in them and I sincerely thank them, once again, for their efforts.

The Commission concluded some time ago that a responsible and knowledgeable press was essential to public involvement, at appropriate times and places in our work. In that regard, we have not been disappointed. I thank all members of the press for the responsible coverage they have given our deliberations.

Once again, thank you all for coming. I declare this Safety Offshore Eastern Canada Conference closed.

APPENDICES

APPENDIX A

WELDING WITH WISDOM;
GAUGING THE RISKS OF ENTERPRISES

Dr. L. Kerwin
President
National Research Council of Canada

It is a pleasure and an honour to meet with this distinguished group which is hard at work on one of humanity's most difficult problems: human safety in complex endeavours. The problem is complex, comprising a multitude of disparate factors. The resulting solution is necessarily a tradeoff, requiring niceties of judgement and intuition. I am not intimately familiar with your specific field, but I do appreciate your difficulties from my work on the Atomic Energy Control Board, where we must license only those nuclear reactors we consider safe; and from work at NRC, where our Building Research Division does research on the safety of buildings. From this background I view your competence and your Conference here in St. John's with both respect and gratitude.

New nuclear reactors, buildings, and drilling rigs will inevitably be constructed, and this means that solutions to the safety problem will certainly be proposed and accepted. But how are these solutions arrived at? First, the experts require facts: solid scientific and engineering data on strength of materials, applicability of construction techniques, environmental parameters, and a host of other things. These facts come from basic research in the sciences. Secondly, come calculations on various component sets, assembled into tentative models. Thirdly, come the non-quantifiable considerations from the realms of sociology, psychology, and (alas!) today's economics. Fourthly, come the intuitive solutions grouping all of these, from which we select, again intuitively, that which best fits the basic facts and the calculated models which we have produced. This intuition which fashions the solution from so many variables is itself an ensemble: we call it wisdom. It is wise men and women who by a complex process find solutions to our most important technical difficulties.

During this Conference, you have been considering many factors which enter into your solutions. Permit me to take an admiring outsider's look at some of them, to illustrate the process by which they are finally welded by wisdom into a safe design solution: a safe reactor, a safe building, a safe offshore drilling rig.

One of these initial factors is risk. Men "that go down to the sea in ships" are generally considered to have a traditional fatalism, to accept risk. But what 'risk' really means is not always clear, particularly to the general public, who sometimes equates it with probability or statistics.

Statistics, or classical probability, is actually quite different from risk. It includes the set of consistent behaviour patterns that we call physical laws. It is inferential and reliable. We use it to predict the future with uncanny accuracy,

because it is founded on a large number of facts about the past. We see; we summarize; we assume the world will keep on working as it has. So far, we have been right.

Classical probability underlies the success of most modern physics and chemistry – its powerful techniques permit it to discern pattern where an unassisted human understanding would bog down in sheer quantity of data. Its subject material is, properly, vast numbers of interchangeable items: atoms, molecules, electrons. The resultant scientific laws are completely dependable. The facts of conductivity of a given copper alloy, or the tensile strength of a given steel, are reliable because the copper and steel artifacts we test comprise myriads of atoms; thus the statistics are excellent. However, what works for the exact sciences does not work for complete offshore structures. If we applied this classical approach, we would build and operate thousands of offshore platforms, then coldly record which sink and which survive. Eventually we could accumulate sufficient correlations to make confident predictions about future platforms. We should also have criminally squandered dollars, years, and lives. Statistical brute force, which works so well for subatomic particles, fails us for units that are neither unmanned nor interchangeable. This is where we switch from probability to risk. We make use of our astonishing human capacity for imagining situations that have never been, for creating a virtual universe of scenarios, and then selecting from this virtual universe the one course that we proceed to make real. To put it another way, the calculation of risk before the event permits us to perform end-runs around the impossibility of using statistics.

It is just this talent, unique to our species, that once won us the moon. No one had been there when President Kennedy announced his goal: there were no classical data. Yet, in July 1969, Neil Armstrong sunk his foot in lunar soil. If this proved possible, may we not dream of ocean platforms of perfect safety? Yes, of course we may; it is why we are here at this Conference.

A second factor is that of cost/benefit, which in turn uses the calculated risk factor as one of its components. In forecasting benefits and costs, it is usual to state relevant factors in identical units, usually fixed-year dollars. In this way we can see more clearly how to tip the scales towards the best solution. Here is how this was done by the United States Food and Drug Administration when it recently set a tolerance for polychlorinated biphenyls (PCBs) in fish for human consumption. It laid out its data in the form of a table, given below.

An Example of Balancing Risk Against Revenue Loss:
The U.S. Food & Drug Administration's Setting of a Tolerance for PCB's in Edible Fish

1	2	3	(3 ÷ 2)
Proposed PCB Tolerance in Parts per Million	Projected Number of New Cancer Cases per Year	Loss of Revenue (Estimated Millions of U.S. dollars)	Dollar Cost of One New Cancer Case (Thousands of U.S. dollars)
5	46.8	0.6	12.8
2	34.3	5.7	166.0
1	21.0	16.0	762.0

Source: U.S. Office of Technology Assessment
(After O'Brien & Marchand, 1982)

Each proposed parts-per-million maximum of PCBs has associated with it an expected yearly number of consequent cancer cases, and a dollar cost due in part to administration costs and to the value of the food jettisoned. By comparing the data sets, which lie in horizontal rows in the above table, we may infer dynamic

data: that is, what happens to one (dependent) variable when another (independent) variable is changed. You can see that as the proposed tolerance rises, the expected yearly number of new cancer cases rises too; and as the proposed tolerance drops, so do new cancer cases we expect. There is a similar direct variation between cancer cases and total cost. In this case, the FDA opted for a PCB tolerance of 2 ppm. This was expected to result in 34.3 new cancer cases per year, and to have a yearly cost (in constant dollars) of $5.7 million U.S.

Why this option? One may possibly infer the answer from dividing each element in the second column into its paired element in the third, deriving a cost per cancer case – a pricetag on life. In the first row, 5 ppm, we are valuing each risked life at about $13,000. Clearly, this is too little. In the other extreme, 1 ppm, the value of each life newly afflicted is almost eight hundred thousand dollars, or more than sixty times as great. The middle way provides a compromise life-worth of about $166,000.

Distasteful as it may seem, the planner must often judge lives in this way. There are extenuations, however, that make this task less ghoulish than it appears. He does not judge ethically, morally, or theologically; the lives he weighs are abstract. To use again the language of physics, they are "virtual" lives rather than real ones. Virtual lives acquire a face only at an actual fatality, an occurrence which the planner bends every effort to avoid. And when a low-risk estimated accident does occur, such as a child falling down a well or a miner being trapped underground, the fact is not accepted just because it was predicted. On the contrary, society then bends every effort and expense, far beyond the original cost/benefit estimate, to get the child out of the well, or the miner out of the cave-in.

Mathematically we call such exercises multivariate analyses or "mini-max solutions"; in every day speech, tradeoffs. Generally, increased safety is purchased by increased cost.

A third factor may be termed "necessary paranoia". This is simply an acknowledgement of the tenuous nature of some of the elements in the process of cost/benefit analysis. Because they deal in numbers and units, these calculations can give us a false sense of security, as if everything they discuss were known to five significant figures. But there are numbers and numbers; not all are equally reliable. Quantum electrodynamics may accurately predict events in the subatomic world to one part in a hundred million billion; but woe betide us if we believe our planner's approximations have the same dependability! In the PCB tolerance table, the route from column 1 to column 2 is tortuous. Going from a given level of tolerances to an end of projected cancer cases involves interbraiding laboratory, epidemiological, and demographic data in a staggeringly complex way. In any quantified risk assessment, then, we must always bear in mind that nothing we produce can be more solid than our assumption set. Data billed as 'hard facts' all too often conceal the wildest guesstimates. Most of the time we simply do not know all the answers necessary for ironclad predictions, and to forget this can invite the very disasters we seek to avoid. When in doubt, then, planners of any large-scale human enterprise must err on the side of safety. Here, if nowhere else, a little paranoia is an eminently desirable thing.

Carrying overdesign too far, however, – "over-overdesigning" – brings us into a situation at once unnecessary and cost-ineffective. If statistical brute force, the mere crunching of vast tracts of data, is an unacceptable way of approaching offshore planning, then the brute force of inelegant overdesign must be unacceptable as well. Paranoia is like spice: a dash of it is salutary, too much ruins the meal. Certainly, there are occasions when the consequences of failure are extreme; and unless we can undertake to trim those risks to acceptable levels, we have no business in the project at hand.

This brings us to a fourth factor affecting our solution: the non-linearity of equivalent probabilities. In classical theory, a one-in-ten chance of winning a dollar is equivalent to a one-in-twenty chance of winning two; a one per cent risk of losing half my bank account is equivalent to a one-half per cent risk of losing it all. Thus, in classical theory, a slight risk of a grave consequence is mathematically the same as a graver risk of a proportionately slighter consequence. For simple cases, things are linear. In the real world, however, such functions cease to be linear for extreme values. If I run one chance in a thousand of losing my life, I most certainly do not run one chance in two thousand of losing two – I have not got the stakes!

Similarly, some eventualities are too terrible not to take every conceivable precaution against, even to a degree not strictly justifiable in mathematics. Let us consider an example. To our knowledge, there has never been a life lost as a direct result of radiation unexpectedly released at a fission powerplant. Hence, based on these data, one could assert the classical probability of death from atomicly-derived electricity is zero. Experience has taught us, however (would that it had not!), that radioactive substances do indeed pack risk, one that often goes unnoticed before it is too late.

Nuclear power plants have therefore been designed with elaborate and redundant safeguards in the form of hardware, controls, and operation techniques. The safeguards, in fact, are more stringent than the probabilities warrant, simply because of the gravity of a worst-case situation. Despite reactor-centuries of use, a core meltdown has never yet occurred in the world. However, even granted that the likelihood of a meltdown is vanishingly small, its consequences, at least for a densely-populated urban area, would be too terrible to utter. Planners of nuclear installations must decide beforehand, in a kind of Hippocratic Oath for their profession, that such a scenario must not occur.

I have selected a deliberately extreme example. A worst-case scenario for an offshore drilling platform has already occurred; leading, among many other things, to our presence here tonight. Yet although we may be speaking of deaths in the tens rather than in the tens of thousands, the principles remain. In a sense, the designers and operators of equipment on the continental shelves must overpower the odds. They must begin with the idée fixe that certain situations must categorically not happen. One might say, paraphrasing Louis St-Laurent (who uttered it of the law), that statistics may also be a humanity; that the non-linearity of equivalent probability must be made to fall on our side.

Seen in this light, even the quantitative exercises of the actuary take on a qualitative, human aspect, and statistics, like pity "bears a human face". Unfortunately, there is more to people than the admirable. If risk statistics is a humanity, it must reflect the bad in people as well as the good. It is probably more cost-efficient to seek out and safely cap all land-based water-wells than to mobilize hundreds of person-days and thousands of dollars in often-futile attempts to rescue a child who has tumbled into one. People do not take such wise precautions: most of us seem to need an actual crisis before we can mobilize and act. Yet such ad hoc heroism is often less truly heroic, i.e. effective, than unglamorous prevention. In a sense, then, the wise designer will save people from themselves, 'idiot-proofing' his or her solutions as much as possible.

A fifth factor in our solution concerns the amplification of corporate responsibility. As we have seen, human nature intrudes into, and places coefficients upon, risk assessment. Most healthy adults, considered as individuals, routinely take risks that no corporation would dare duplicate. Consider what the bulk of us private citizens do daily. We sleep in houses laced with electrified cables, which we seldom bother to check. We use poison-gas generators to drive to work, heat our houses, and barbeque our food. We walk blindly in that deadliest of hazards, the slippery bathtub. We operate power tools with nothing protecting our irreplaceable

Dr. Kerwin earned his Doctor of Science degree from Laval University in 1949 after obtaining a M.Sc. from the Massachusetts Institute of Technology in 1946. He has received numerous awards and honorary degrees. In 1980 Dr. Kerwin was appointed to a five-year term as President of the National Research Council of Canada where he contributed to building a national awareness of the importance of research and development to the well being of the nation. In 1982 he was appointed Canada's representative on a working group set up as a result of the June 1982 Economic Summit, to study how research and development can be used to create jobs and help the world economy to recover. The working group is made up of representatives of the seven Economic Summit nations and one from the European Economic Community.

eyes. But we do not condone such cavalier behaviour when we work as a group; for corporately, we humans are far more conservative. The same people who mow their own lawns wearing tennis shoes are forced by law to wear steel-toed shoes on a public grounds crew.

Clearly, we must eschew all individual flippancy when we go to face the northern seas. For one thing, those who make the plans are usually not those who face the risks. If I mow my toe off, it is my own fault; if my inattention results in the injury or death of my fellows, then they have reaped the consequences I myself deserve but have escaped. The very size of our enterprise makes this more critical, for sufficient quantitative change creates qualitative change. Lawn-mowing and offshore exploration are so different in hours, dollars, and person-years that they become different in essence as well.

There is a vital sixth factor which must enter our solution. There is yet another way in which human nature intervenes to modify the chaste numerical predictions of risk assessment. Risk itself may form part of what attracts workers to the danger and discomfort of an offshore platform. Risk confers status, both directly and by means of pay and benefits. Is a rig that seems as safe as one's living room not liable to have difficulty recruiting the best workers? Further, a paradoxically greater danger may lurk in an environment that is too obviously safe. With the removal of apparent threat, people get careless. Crew quarters with wall-to-wall broadloom, pools, and video arcades are still perched a few metres above disaster on an unforgiving ocean. Designers may forget this; workers may forget this; but the sea never will.

As is true in so many other areas, the appropriate response to this threat is awareness. 'Raw' high risk need not lead to accident so long as those at risk recognize the fact and govern themselves accordingly. Ask yourself what would happen if summertime drivers stopped taking the road for granted, and drove as if it were winter, accelerating slowly, braking smoothly, behaving as gingerly as if the roads were ice. And while the absolute prevention of risk may not be within our grasp – risk, after all, being part of life – we may be able to go along indefinitely without a major accident. A situation where accidents cannot happen, where the simple operation of natural law forbids them, is doubtless unattainable. A situation where accidents do not happen, may well be within our grasp. In that sense, our human consciousness can become part of natural law. A judicious blend of good design, good operations methods, and training may keep tragedy forever from the door.

I have mentioned six factors which enter into the process of determining a solution to the complex problem of human safety in a major endeavour. Each of the six is important; the expert sees them standing in a row, waiting to be combined, somehow, into a solution. First the risk assessment, that end-run around the statistics; second the cost/benefit figures, which must lie in the realm of the possible; third, that nice dosage of paranoia, which often makes a solution more acceptable; fourth, the non-linearity of equivalent probabilities, which categorically excludes the worst-case solution; fifth, the amplification of corporate responsibility; sixth, the leavening of awareness.

To the judicious and acceptable melding of these, the expert must himself bring the ultimate factor: wisdom. I have discussed the nature of excellence on other occasions, and the nature of wisdom is akin to it. Its recognition is, ultimately, the fruit of generations of honed experience.

In their wisdom, then, the experts judge the optimum solution from the numerous virtual solutions which they can assemble in their imaginations out of all the basic components. For problems of human safety, the cardinal virtue which their wisdom brings to bear is charity, or disinterested love. In facing the question "How safe can we afford to make our offshore installations?" we must really ask

ourselves: "How much do we care about the people on them?" This will modulate our strict cost/benefit equations, and further make our statistics into a humanity. The human lives we deal with, however virtual or theoretical, will then appear more real as we remember that every individual on Earth is fundamentally priceless. Indeed, if we regard the lives of those who venture into stormy seas as themselves of greater worth than anything they may obtain, we will be physically unable to create an offshore enterprise prone to disaster. Such will be the solutions of wise people, fashioning from carefully-prepared factors, and with love, a solution that will be equally acceptable in its engineering, economic, and human aspects. There may yet be other disasters, borne of solutions which were not thus fashioned by wisdom or animated by charity; these are statistics that the future will provide. But I sense already that the efforts of the Commission, and of the wise people at this Conference, will render such disasters vanishingly rare.

APPENDIX B

MAIN SPEAKERS

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APPENDIX C

DISCUSSANTS

Mr. F. Atkinson
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Mr. F.H. Atkinson is a Naval Architect and Chartered Engineer who has been with Lloyd's Register of Shipping for 29 years. He has authored a number of papers on the safety of tankers and offshore structures. A member of the Science and Engineering Council, Mr. Atkinson is currently the Head of the Offshore Services Group of Lloyd's Register of Shipping.

Dr. C. Brooks
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Dr. C. Brooks served in the Royal Navy's Submarine Service from 1965 to 1970. After 5 years' private practice as a family physician, he became Flight Surgeon at Shearwater, Nova Scotia, and was involved in search and rescue. He holds post-graduate degrees in both occupational and aviation medicine, and has carried out research and development for the last 6 years into restraint systems, emergency suits, hypothermia, and life preservers at the Defence and Civil Institute for Environmental Medicine.

Mr. I. Denness
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Mr. Ian Denness has spent a number of years at sea onboard tankers, and has qualified as Chief Engineer. In the last 5 years he has been in the offshore safety field, both in the U.K. and Canada. Currently with Gulf Canada Resources, Mr. Denness is also Chairman of a Canadian General Standards Board Working Group which is developing a standard for helicopter immersion suits, and he is Chairman of the CPA Offshore Operators Division Safety Committee.

Mr. L. Draper
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Mr. L. Draper is Consultant Oceanographer to the Institute of Oceanographic Sciences in the United Kingdom. He has a specialized interest and expertise in waves, and was at one time Director of the Canadian Wave Climate Study.

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Dr. H. Haakonson is currently Corporate Medical Director for Petro-Canada. He has spent 24 years in the military service, and as Command Surgeon, Maritime Command, Halifax, he was responsible for the medical care of all military personnel in Maritime Canada.

Mr. T. Haavie
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Mr. Thor Haavie is a Naval Architect with 14 years experience in semisubmersible design. He was a member of the Aker H3 Design Group, and has designed the SSV *Uncle John* and the SSV *Stadive*. He is currently the Managing Director of Submarine Engineering in Aberdeen.

Mr. J. Hielm
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Mr. J. Hielm worked in Norwegian air traffic control, specializing in air/sea rescue work, from 1951 to 1970, and joined the Norwegian Rescue Service when it was established in 1970. In 1975 he joined Elf Aquitaine Norge as Section Head, and has since then presented papers on contingency planning to several international conferences.

Dr. G.R. Lindsey
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Dr. G.R. Lindsey has degrees from Toronto, Queen's and Cambridge and has worked in the areas of nuclear physics, operational research, strategic studies and future studies. He is a Past President of the Canadian Operational Research Society, and since 1967 he has been Chief of the Operational Research and Analysis Establishment of Canada's Department of National Defence.

Mr. W. Martinovich
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Mr. W. Martinovich has extensive experience in marine vessel design which has gained him an international reputation. He has worked with Earl & Wright since 1956 and managed the design of their first semi-submersible, the *Bluewater 2*, in 1963. He has also guided the development of the *SEDCO H*, 600, 700, and 800 design series, and is a Director of SEDCO, Inc. He has been Executive Vice-President of Earl & Wright since 1979.

Mr. D.J. Riffe
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Mr. D.J. Riffe holds Bachelor's degrees in Fire Protection Engineering and Industrial Safety Engineering, and a Master's degree in Environmental Science. In 1981, after a broad base of experience in safety engineering in a number of different industries, Mr. Riffe joined Gulf Research & Development Co., where he is currently in the Oil Exploration & Production Division co-ordinating fire protection, safety and environmental engineering on several offshore projects.

Dr. B.P.M. Sharples
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Dr. B.P.M. Sharples has a Ph.D. in Structural Engineering and has been associated with the oil industry throughout his professional life. Since 1970 Dr. Sharples has been extensively involved in the preparation for towing, installation, and operations of a wide variety of steel and concrete platforms, both mobile and fixed. He is currently President of Noble, Denton and Associates.

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